

Past, Present, and Future of Biomedical Information

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
National Institutes of Health

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Foreword

Nineteen eighty-six marked the 150th year of the National Library of Medicine. Among the many observances of that anniversary was a special day—September 16—devoted to both looking back at our history and forward to the challenges of the future.

This traditional exercise was particularly appropriate because the Library has been over the course of its 150 years a leading force in almost every aspect of information management and because five panels of distinguished outside experts had just reported to the Board of Regents their view of the future as input to the Board's preparation of a long range plan.

To bring to life our past we were fortunate to have the observations of two former directors of the National Library of Medicine. To elucidate the future we heard from the chairperson or co-chairperson of each of the five planning panels. This volume records their observations.

Harold M. Schoolman, M.D.

Deputy Director, National Library of Medicine

Colloquium Organizer

On July 27, 1987, Frank Bradway Rogers, M.D., director of the National Library of Medicine from 1949 to 1963, died. He will be remembered as a man of scholarly accomplishment and administrative skill. That he was a master of the language may be seen from his presentation, "The Old Library in Washington" (pages 16-26). This volume is dedicated to his memory.

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Morning Session

Introduction

Moderator: Lieutenant General Quinn H. Becker
Surgeon General, U.S. Army

It is a great privilege and pleasure for me to be here this morning. The Army Surgeon General and the Army Medical Department had a great part in the history of this library. The Library might have "happened" anyway, but the Army is proud of its long involvement with the institution.

In a sense, I am representing Surgeon General Joseph Lovell, who started the Library 150 years ago. He would be proud today to be here in my place and to see and hear how the Library has evolved.

Another who would take pride in the institution, is John Shaw Billings. He would no doubt recall the evenings in his Georgetown home when he would have delivered great baskets full of journals that he would spend long hours indexing. Oliver Wendell Holmes, in describing Billings' propensity for collecting, said that he was "a danger to the owner of any library."

We will no doubt hear other such fascinating anecdotes as our three speakers this morning talk about "the Library past."

The Early Development of Medical Libraries in America

John Parascandola

The subject of this symposium volume is the National Library of Medicine, its past, present and future. The two papers which follow look back at the history of the Library. My task is to set the background for the NLM story by briefly examining the development of medical libraries in America largely in the period before the establishment of the Army Surgeon General's Library, the precursor of today's National Library of Medicine.

In 1836, the year that we celebrate as marking the formal birth of the Surgeon General's Library, there were only some twenty odd medical libraries in the United States (see Table I).¹ None of these would seem very large to us by today's standards. The largest by far was also the oldest, the medical library associated with the Pennsylvania Hospital, which at the beginning of the decade of the 1830s contained somewhat over 5,000 titles.²

Founded in 1751, the Pennsylvania Hospital was the first hospital in Britain's American colonies. It antedates the founding of any American medical school and of all but a few relatively short-lived American medical societies, so it is not surprising that it should have been the home of the earliest medical library in this country. Although certain donors left "pious books" at the hospital's door for the comfort and edification of patients, it was not until 1762 that the institution received its first medical book. Dr John Fothergill of London donated a copy of William Lewis' *Experimental History of the Materia Medica*, published in the previous year, for the benefit of students studying under the direction of hospital physicians.³

In 1763 the hospital established a fee for students who came to attend the practice of hospital physicians, and decided to use the funds collected to found a medical library. In addition to books purchased with these funds, the library grew in size through the donation of individual items and collections. Of course, they soon faced a problem familiar to libraries today, namely the gifts of unwanted books. Already in 1775, an inventory was made of "Books not Medical contained in a Trunk in the Managers Room." The inventory lists a Bible, some Latin and Greek grammars, dictionaries, and various works on religion and philosophy, as well as something referred to simply as "Old Manuscript."⁴

A catalog of the library published in 1790 listed some 350 titles.⁵ The rules of the library stated that the librarian would be in attendance on "every Fourth and Seventh-day morning, from nine till eleven o'clock, to receive and lend out books." Borrowing privileges were restricted to managers and physicians of the hospital and their students, as well as to other approved medical students paying a fee. Only two books at a time could be checked out, and it is interesting to note that the length of time a book could be kept depended upon its size. An octavo volume, for example, could only be kept for two weeks, while a folio volume could be kept for four weeks. (This same system of using size for determining the length of time for which a book could be checked out was followed by a number of the other early medical libraries discussed below.) Fines for overdue books were specified, and borrowers were responsible for lost or damaged books.⁶

Another hospital which established a library before the end of the eighteenth century was the New York Hospital, which had been founded in 1770. The library was apparently founded in 1796, and its published rules in 1804 are very similar to those noted earlier for the Pennsylvania Hospital.⁷ The board of another early hospital, the Philadelphia Almshouse, requested funds in 1805 for a room to house a library. By 1808 work on such a room had begun and one hundred and fifty dollars was appropriated for the purchase of books to be selected by the physicians of the institution. Within a decade the library contained more than a thousand volumes.⁸

It should be noted that the position of librarian was not a full-time one in any of these three early hospital libraries, but was combined with other duties. In each of these three cases, the librarian, for at least a significant portion of the institution's early history, was the apothecary.⁹ Why were the duties of the librarian associated with the apothecary in these hospitals?

I think the answer lies in the broader role of the apothecary in early American hospitals. These hospitals largely followed the model of British voluntary hospitals in hiring a full-time salaried apothecary. In the British system, and consequently also in British North America, the apothecary performed many medical duties in addition to filling prescriptions for medicines. In British hospitals, for example, the apothecary was often in charge of the daily bleedings, supervised the baths, looked after the surgical instruments, and sometimes served as steward or secretary as well. John Woodward has noted that the apothecary was generally the "only full-time resident member" of the medical staff, and "was the keystone of medical practice by virtue of his constant attendance." He frequently shouldered the main burden of responsibility in the hospital.¹⁰

This pattern carried over to America. At the Pennsylvania Hospital, for example, the apothecary was the highest salaried member on the staff during the colonial period. The apothecary lived in the hospital, acted as pharmacist and house physician, and sometimes also as steward and instructor to the apprentices.¹¹ It should not be surprising then that the operation of the library was also commonly made one of the responsibilities of the apothecary in early American hospitals.

Besides hospitals, early medical libraries were also found in some of the medical colleges. We must look to Philadelphia again for the lead in medical education as well as in hospital care, for the oldest medical school in America was established at the University of Pennsylvania in 1765. The first two professors appointed at this institution were the well known physicians William Shippen and John Morgan. Morgan was an advocate of a strong library at the newly founded medical college, and suggested that an annual fee be levied on the students to help support the purchase of books. Apparently the library was not well supported, however, and the institution remained without a decent medical library for over a century.¹²

Several of the New England colleges established medical libraries at an early date. The Harvard Medical School, for example, apparently had a library associated with it since the school itself was organized in 1782.¹³ Harvard's medical library was greatly expanded in 1800 when Ward Nicholas Boylston gave the medical school 1100 volumes, laying the foundation for the Boylston Medical Library, whose early catalogs give its date of institution as 1802.¹⁴ By 1824, the library's catalog listed over 500 titles. Medical libraries were established at Dartmouth in 1797, at Yale in 1814, and at Bowdoin College (Medical School of Maine) in 1820.¹⁵

Moving south along the east coast, a library was established at the College of Medicine of Maryland, later the University of Maryland Medical School, only six years after it was founded in 1807. Maryland acquired the nucleus of a library in one fell swoop when it purchased the books of Dr. John Crawford upon his death in 1813. The collection apparently consisted of more than 400 volumes.¹⁶ Also in the southeast, a library was founded at the Medical College of Georgia in 1834.¹⁷

The first medical library in what was then the American west was probably that at Transylvania University in Kentucky. The Medical Department of that institution was founded in 1799, although it was apparently not until 1816-1817 that a well-organized Medical Department was conducted. Its medical library, which was well supported, soon came to be regarded as one of the best in the country. In 1820, for example, a faculty member was reportedly sent to Paris with \$13,000 to purchase medical books.¹⁸ Another early medical school in the west was the

Medical College of Ohio, founded in Cincinnati in 1819. Its primary founder was a former faculty member at Transylvania University, the celebrated Daniel Drake. Before instruction actually began in 1820, the college had amassed a library of more than 500 volumes.¹⁹

I should mention in passing that in addition to these medical libraries, the two schools of pharmacy founded in this country before 1836, in Philadelphia and in New York, also had libraries associated with them.²⁰

It should be pointed out that libraries in American medical schools remained relatively small throughout the 19th century. Writing of medical education in the United States before the Civil War, William Norwood commented:

"Every medical college had a collection of books called a library. At times it was little more than the private collection of the professors. Any school that could boast a collection of several hundred or more volumes usually made special mention of the library in its circulars and catalogues. Most libraries contained three hundred to fifteen hundred volumes."²¹

Another medical historian, Whitfield Bell, Jr., has pointed out that of fifty-nine medical libraries reporting more than 10,000 volumes in 1891, not one was in a medical school. Harvard, for example, had a medical library consisting of 1,500 volumes at the time, as contrasted with over 28,000 volumes in its Law School and over 23,000 volumes in its Divinity School.²² An 1898 survey of medical libraries in the United States was able to obtain reports of libraries from only 24 of the 165 medical colleges in the United States (in addition to reports from six pharmacy schools and one veterinary college).²³

Even John Shaw Billings, who built the Army Surgeon General's Library from a small collection of books to the largest medical library in the world, was rather pessimistic about medical school libraries. Writing in 1876, Billings stated:

"It may be noted here that almost all attempts to establish medical libraries in connection with medical schools have been failures. Commenced with enthusiasm, they soon become antiquated, are rarely consulted, except by one or two species of beetles, are never properly catalogued or cared for, and dust and mould reign in them supreme. Students and teachers want the newest books only. Libraries are used by the scholar and author, and for such are the true universities."²⁴

Thus, as Whitfield Bell, Jr. has noted, while medical schools of the nineteenth century might have recognized the need for a collection of current journals, a large retrospective collection of books was often considered a luxury.²⁵ For "the scholar and author," to use Billings' phrase, it might be sufficient to have one large medical library in the area which could be consulted when the need arose. Billings believed, for example,

that The Johns Hopkins Medical School would not require a large medical library since the Surgeon General's Library was only an hour away.²⁶ It was sometimes suggested that each principal city should establish its own public medical library, perhaps pooling the resources of several libraries.²⁷ Even a strong advocate of the importance of medical libraries like Denver physician C. D. Spivak stated in a report on the subject in 1898 that there was no necessity of having more than one such library in any city.²⁸

The third type of institution that sometimes housed a medical library in early America, besides the hospital and the medical school, was the medical society. The first of these known to have contained a significant library was the Massachusetts Medical Society, which claims to be the oldest medical society in the United States with a record of uninterrupted meetings from its founding.²⁹ The library was mentioned in the society's first by-laws when it was founded in 1782. The first librarian was Aaron Dexter, Professor of Chemistry and Materia Medica at the Harvard Medical School. During the early decades of the society, the books were housed in the home of the librarian, moving as this position changed hands. It was apparently not until at least 1810 that accommodations were found for the books outside of the home of the librarian.³⁰

Another early medical society in the United States was the College of Physicians of Philadelphia, founded in 1787. The very next year after the organization of the College, a committee was appointed to draft a plan for a library, and such a plan was approved in 1789. The first funds for the purchase of books were authorized shortly thereafter.³¹ During the pre-1836 period under review in this paper, however, the library of the College of Physicians was not the important resource for medical literature which it later became. In 1835, it contained fewer than 300 volumes, was reported to be in bad condition, and not a single volume had been called for in over a year.³²

The Medical Society of South Carolina was organized two years after the College of Physicians, in 1789, and by 1791 had begun to collect books for a library. By 1834 the collection had grown to about 2,000 volumes.³³ Other society libraries founded before 1836 include those of the Medical and Chirurgical Faculty of the State of Maryland and district or county societies in the District of Columbia, in Salem and Worcester, Massachusetts, and in Buffalo, New York.³⁴

A somewhat special case is the Boston Medical Library. I refer here to the original library of this name, and not the later one founded in 1875. This first Boston Medical Library was the result of an act passed in Massachusetts in 1798 which allowed any seven or more persons in a town or district to form themselves into a society for the purpose of

managing a library of which they were the proprietors. These libraries were to be called "social" libraries, meaning that they were owned by proprietors or partners who managed and used the books for their own purposes, as opposed to circulating libraries, whose purpose was to make a profit for their owners. The Boston Medical Library was founded in 1805 as such a "social library." It was established by members of the Medical Improvement Society, and at first the books were kept at the home of Dr. John Fleet, who served as the first librarian. Later they were moved to the apothecary shop of Amos Smith, the sub-librarian, and then into a building shared with the Harvard Medical School and the Massachusetts Medical Society.

In 1826, for reasons which are not entirely clear, the collection of the Boston Medical Library was ceded to the Boston Athenaeum. This step seems to have been part of an effort to unite many of the library collections in Boston in the Athenaeum, thus creating one major library which could overcome the deficiencies of smaller libraries. For a time the collection of the old Boston Medical Library still preserved some of its former identity, but eventually it came to be considered as merely a part of the Athenaeum library.³⁵

As with the hospitals, and no doubt also the medical schools, these early society libraries were served by part-time librarians, ordinarily physician members. Probably they were not paid or received only a small stipend. And in some cases a requirement for being selected as librarian must have been an ability and a willingness to house the books in one's own home.³⁶

In addition to these distinctly medical libraries discussed above, there were at least some general libraries which contained significant collections of medical books. I have already mentioned the Boston Athenaeum, which had a medical collection associated with it that had grown to some 3,000 volumes by 1849.³⁷ And of course a number of physicians had large personal collections of medical books, but such private collections are beyond the scope of my paper.³⁸

I have briefly described the situation of medical libraries in the United States before the founding of the Surgeon General's Library. To summarize, there were only some twenty or so identifiable medical libraries in existence in this country in 1836, and these were located in one of three types of institutions: hospitals, medical schools, or medical societies. These collections were by and large relatively small, ranging from a few hundred to a few thousand volumes. The librarians during the period under discussion in this paper were usually physicians or apothecaries who served as volunteers and/or as a part of broader job responsibilities, and generally did so on a part-time basis.

Throughout much of the nineteenth century, medical libraries did not have the importance in America that we attribute to them today. The situation was beginning to change by the turn of the twentieth century, however. By this time, historian Whitfield Bell, Jr. argues, "medical libraries had come to be recognized generally as one of the indispensable engines for the advancement and dissemination of knowledge."³⁹ The founding of the Association of Medical Librarians (later the Medical Library Association) in 1898 was both a reflection of this changing attitude and a contributor towards it, as the Association actively fostered the development of medical libraries. Clearly another factor contributing towards the increasing recognition of the importance of medical libraries was the dramatic growth of the Surgeon General's Library and the bibliographic efforts of its Director, John Shaw Billings, in the closing decades of the century, a subject which is discussed in the next paper.

Acknowledgements: I would like to especially thank Margaret Kaiser, reference librarian in the History of Medicine Division, National Library of Medicine, for valuable assistance in locating some of the information and source materials used in preparing this paper. I also wish to express my appreciation to two other colleagues in the Division, Philip Teigen and James Cassedy, for reading an earlier draft of this paper and making useful suggestions for improvements.

Notes and References

1. It is difficult to determine the exact number of such libraries. Joseph Jensen and In-greet Weisheit-Smith, "History of the library of the Medical and Chirurgical Faculty of the Stats of Maryland," *Md State Med J*, 29(June, 1980): 35-48 claim there were 22 known medical libraries in North America prior to 1830 (p. 39), but do not list the institutions and provide no documentation for this statement. My own estimate of 24 (including two pharmacy school libraries) founded by 1836 is in substantial agreement with their claim (see Table I). In identifying these libraries, I started with the table of "General statistics of all public libraries in the United States" in *Public Libraries in the United States of America: Their History, Condition, and Management*, Special Report, Department of the Interior, Bureau of Education (Washington, D. C.: Government Printing Office, 1876), pp. 1010-1142, but I added several libraries not identified in this table, as well as eliminating one. The founding dates that I have given, based upon the many sources cited below, are not always in agreement with those listed in the table in *Public Libraries*. This report contains a useful chapter on "Medical libraries in the United States" by J. S. Billings, pp. 171-182.

2. Whitfield J. Bell, Jr., "The old library of the Pennsylvania Hospital," *Bull Med Lib Assoc*, 60 (1972): 543-550, p. 549.

3. *Ibid.*, p. 543.

4. *Ibid.*, pp. 543-545.

5. *A Catalogue of the Books Belonging to the Medical Library in the Pennsylvania Hospital* (Philadelphia: Zachariah Poulson, 1790).

6. *Ibid.*, pp. 3-5.

7. *Public Libraries* (N. 1), P. 1096; *A Brief Account of the New York Hospital* (New York: Isaac Collins and Son, 1804), pp. 1-6, 42-45.

8. John W. Croskey, *History of Blockley: A History of the Philadelphia General Hospital from Its Inception, 1731-1928* (Philadelphia: F. A. Davis, 1929), pp. 45-46. Although the Philadelphia Almshouse was founded twenty years before the Pennsylvania Hospital, and probably provided some medical care to inmates from the beginning, the primary function of the former institution was not hospital care at the time, and so the latter is usually considered to be the first American hospital.

9. *Ibid.*, p. 45; E. F. Rivinus, *A Catalogue of the Medical Library of the Philadelphia Almshouse* (Philadelphia, 1831), p. vi; Bell, "The old library" (n. 2), pp. 545-546; *New York Hospital* (n. 7), p. 42. The pattern was the same at the only other hospital on my list, the Northern Dispensary of Philadelphia, whose library was founded in 1825, according to *Public Libraries* (n. 1), p. 1122 (although I have not been able to confirm this date). The rules of the dispensary for 1842, e.g., list "the care of the Library" as one of the duties of the apothecary. See *Act of Incorporation, By-laws and Rules and Regulations of the Northern Dispensary, for the Medical Relief of the Poor* (Philadelphia: J. Van Court, 1842), p. 8.

10. John Woodward, *To Do the Sick No Harm: A Study of the British Voluntary Hospital System to 1875* (London: Routledge and Kegan Paul, 1974), pp. 28-29.

11. William H. Williams, *America's First Hospital: The Pennsylvania Hospital, 1751-1841* (Wayne, PA: Haverford House, 1976), pp. 48-52.

12. George Corner, *Two Centuries of Medicine: A History of the School of Medicine, University of Pennsylvania* (Philadelphia: J. B. Lippincott, 1965(p. 23); Whitfield J. Bell, Jr., "Private physicians and public collections: medical libraries in the United States before 1900," in Lloyd G. Stevenson, ed., *A Celebration of Medical History: The Fiftieth Anniversary of the Johns Hopkins Institute of the History of Medicine and the Welch Medical Library* (Baltimore: Johns Hopkins University Press, 1982), pp. 85-102, see p. 87. The University's medical library was not even mentioned, e.g., in 1871 in Richard J. Dunglison, *The Public Medical Libraries of Philadelphia* (Philadelphia: J. B. Lippincott, 1871), which discussed the collections of the Philadelphia College of Physicians, the Pennsylvania Hospital, and the Philadelphia Almshouse. Dunglison then went on to say (p. 46): "The nuclei of other libraries may be found in several of our medical institutions; but none of them has yet risen to such importance as to deserve special mention, though hereafter they may become of historic interest."

13. Henry Beecher and Mark Altschule, *Medicine at Harvard: The First Three Hundred Years* (Hanover, NH: University Press of New England, 1977), p. 30; William F. Norwood, *Medical Education in the United States Before the Civil War* (Philadelphia: University of Pennsylvania Press, 1944), pp. 170-172.

14. Thomas Harrington, *The Harvard Medical School: A History Narrative and Documentary, 1782-1905* (New York: Lewis Publishing, 1905), p. 272; *Catalogue of Books in the Boylston Medical Library at Harvard University* (Boston: Ezra Lincoln, 1824). 15. Norwood, *Medical Education* (n. 13), pp. 187, 202; Carleton Chapman, *Dartmouth Medical School: The First 175 Years* (Hanover, NH: University Press of New England, 1973), pp. 12-13; Frederick Kilgour, *The Library of the Medical Institution of Yale College and Its Catalogue of 1865* (New Haven: Yale Medical Library, 1960), pp. 10-11; George Little, "Historical sketch," in *General Catalogue of Bowdoin College and the Medical School of Maine, 1794-1894* (Brunswick, ME: Bowdoin College, 1894), pp. ix-cxii, see p. cii; Avanelle Morgan, "The Medical School of Maine at Bowdoin College (1820-1921)," *J Me Med Assoc*, 68 (1977): 315-319.

16. Julia E. Wilson, "An early Baltimore physician and his medical library," *Ann Med Hist*, third series, 4 (1942): 63-80; Ida M. Robinson, *The Health Sciences Library, University of Maryland: A History, 1813-1960* (n.p., n.d.).

17. Gerald Cates, *A Medical History of Georgia: The First Hundred Years, 1733-1833*, Ph.D. diss., University of Georgia, 1976, p. 188; W. H. Goodrich, *The History of the Medical Department of the University of Georgia* (Augusta, GA: 1982), p. 194.

18. Norwood, *Medical Education* (n. 13), pp. 289-294.
19. *Ibid.*, pp. 304-305.
20. *Public Libraries* (n. 1), pp. 1093 and 1123. The Philadelphia College of Pharmacy seems to have begun to build up a library from its founding in 1821. See Joseph England, ed., *The First Century of the Philadelphia College of Pharmacy, 1821-1921* (Philadelphia: Philadelphia College of Pharmacy, and Science, 1922), p. 65, and *The Druggist's Manual* (Philadelphia: Philadelphia College of Pharmacy, 1826), pp. viii, 113-117. Although the New York College began soliciting donations of books from its founding in 1829, it apparently was not immediately successful. It would appear to still have been a very small collection in 1836, and in the 1850s the President of the College said that with a few exceptions its volumes were suited only for the shelves of the antiquarian. See Curt Wimmer, *The College of Pharmacy of the City of New York, Included in Columbia University in 1904: A History* (New York: The College of Pharmacy of the City of New York, 1929), pp. 23-26, 41, 49.
21. Norwood, *Medical Education* (n. 13), p. 398.
22. Bell, "Private physicians" (n. 12), pp. 94-95.
23. C. D. Spivack, "The medical libraries of the United States," *Phila Med J.* 2 (1898): 851-858, see pp. 852-853. This article contains a table of medical libraries in the United States (pp. 854-856), which includes information on medical collections in general libraries. There are errors, however, in many of the founding dates listed. The same comments may be made about another table of medical libraries in Albert Huntington, "The medical library movement in the United States," *Med Libr Hist J*, 2 (1904): 119-128, see pp. 120-126.
24. J. S. Billings, "Literature and institutions," in Edward H. Clarke, Henry J. Bigelow, Samuel D. Gross, T. Gaillard Thomas, Henry J. Billings, *A Century of American Medicine, 1776-1886* (Philadelphia: Lea, 1876), pp. 291-366, see p. 351.
25. Bell, "Private physicians" (n. 12), pp. 95-96.
26. *Ibid.*, p. 95.
27. Spivack, "The medical libraries" (n. 23), pp. 852-853; John P. Harrison, "Report of the Committee on Medical Literature," *Trans Am Med Assoc*, 2 (1849): 371-419, see pp. 417-418.
28. Spivack, "The medical libraries" (n. 23), p. 852.
29. Walter L. Burrage, *A History of the Massachusetts Medical Society* (privately printed, 1923), p. 1.
30. *Ibid.*, pp. 388-400.
31. Dunglison, *Public Medical Libraries* (n. 12), pp. 3-6; W. S. W. Ruschenberger, *An Account of the Institution and Progress of the College of Physicians of Philadelphia During a Hundred Years, from January, 1787* (Philadelphia: Milliam J. Dornan, 1887), p. 24.
32. Bell, "Private physicians" (n. 12), pp. 87-88.
33. Joseph Waring, *A History of Medicine in South Carolina, 1825-1900* (n.p.: South Carolina Medical Association, 1967), pp. 97-98.
34. Jensen and Weitshiet-Smith, "History of the library" (n. 1); *History of the Medical Society of the District of Columbia, 1817-1909* (Washington, D.C.: Medical Society of the District of Columbia, 1909), pp. 40-41; *Catalog of the Library of the Worcester District Medical Society* (Worcester: Charles Hamilton, 1860), p. iii; *By-laws of the Medical Society of the County of Erie: Together with the Laws of the State of New-York, Relative to the Medical Profession, and a System of Medical Ethics* (Buffalo: Charles Faxon, 1834), pp. 2-3. As for the Essex South District Medical Society in Salem, Massachusetts, although I have not been able to confirm the 1805 founding date given in *Public Libraries* (n. 1), p. 1061, the library was certainly founded well before 1836 as attested to by the fact that Dr. Edward Holyoke bequeathed some of his books to the Society's library upon his death in 1829. See *Memoir of Edward A. Holyoke, M.D., LL.D.* (Boston: Perkins and Marvin, 1829). The Essex South and the Worcester societies were also borrowing substantial numbers of books for long periods of time from the Massachusetts Medical Society by the 1820s. See Burrage, *History* (n. 29), pp. 402-403.
35. John W. Farlow, *The History of the Boston Medical Library* (privately printed, 1918), pp. 13-31.

36. Evidence for the part-time, volunteer nature of these early librarian positions may be found in a number of the sources cited above. See, e.g., Ruschenberg, *Account* (N. 31), p. 194; Jensen and Weitsheit-Smith, "History of the library" (n. 1), pp. 40-41.

37. Harrison, "Report" (N. 27), p. 417.

38. For information on some of these private collections, see Bell, "Private physicians" (n. 12).

39. *Ibid.*, p. 96.

Table I. American Medical Libraries Established by 1836

<i>Name of Institution</i>	<i>Library Founded</i>
Pennsylvania Hospital	1763 ^{2, 3}
University of Pennsylvania Medical Department	1765 ¹²
Massachusetts Medical Society	1782 ³⁰
Harvard Medical School	1782 ^{13, 14}
Philadelphia College of Physicians	1789 ³¹
Medical Society of South Carolina	1791 ³³
New York Hospital	1796 ⁷
Dartmouth College Medical Department	1797 ¹⁵
Worcester District Medical Society, Massachusetts	1798 ³⁴
Boston Medical Library	1805 ³⁵
Essex South District Medical Society, Massachusetts	1805 ^{7, 34}
Philadelphia Almshouse	1808 ^{8, 9}
Medical College of Maryland	1813 ¹⁶
Yale University Medical Department	1814 ¹⁵
Transylvania Medical College	1816 ^{7, 18}
Medical Society of the District of Columbia	1818 ³⁴
Medical College of Ohio	1820 ¹⁹
Medical School of Maine (Bowdoin College)	1820 ¹⁵
Philadelphia College of Pharmacy	1821 ²⁰
Northern Dispensary of Philadelphia	1825 ^{7, 9}
College of Pharmacy of the City of New York	1829 ^{7, 20}
Medical and Chirurgical Faculty of the State of Maryland	1830 ³⁴
Medical College of Georgia	1834 ¹⁷
Erie County Medical Society, New York	1834 ^{7, 34}

Only separate medical libraries (including two pharmacy school libraries) are listed, and not general libraries containing medical sections. The founding dates are based on information in the sources cited in the

notes indicated above. A different interpretation of what is meant by "founding," of course, could in some cases lead someone else to choose a somewhat different date. Cases where I feel there is significant uncertainty about the founding date are indicated by a question mark. I have not included three libraries (Jefferson Medical College; Medical Department of the University of Louisiana, later part of Tulane University; and University of Virginia) which at least one source listed as having had a library before 1836 because I felt that the preponderance of evidence indicated a post-1836 founding data.

The Old Library in Washington, 1836-1961

Frank Bradway Rogers

The Beginning

In 1836 Alexis de Tocqueville was in the midst of publishing his *Democracy in America*, Ralph Waldo Emerson in Concord was receiving his first visit from feminist Margaret Fuller, and in nearby Cambridge a proud Harvard College was spending \$5,000 a year to support its library and was getting ready to celebrate its 200th anniversary. In a young Washington City, the Library of Congress was purchasing a foreign library of some 25,000 volumes, which would double the size of its collections. The legacy for establishing the Smithsonian Institution had just been announced. The occupant of the Executive Mansion was Andrew Jackson, and across a muddy Pennsylvania Avenue lived the Surgeon General of the Army, Joseph Lovell, in Blair House, which he had built.

Dr. Lovell's administration of the Army Medical Department is notable for several contributions, among them his support, over more than a decade, of the research of Dr. William Beaumont, whose book *Experiments and Observations on the Gastric Juice, and the Physiology of Digestion*, published in 1833, was then and is now one of the great monuments of medicine. Lovell encouraged Beaumont to spend a few months in Washington, in the winter of 1832-33, studying the literature of digestion¹; no doubt some of the books which Beaumont read were provided by the Surgeon General's Office.

We do know that during Lovell's term in office, 1818-1836, about \$400 per year was spent on procurement of medical books and journals. Most of these were in multiple copies, intended for surgeons at distant posts; some few titles were for the exclusive use of Dr. Lovell's immediate office. Traditionally, the year 1836 has been accepted as the Library's founding year; that was Lovell's last year, and it was the year in which a budget submission for the Surgeon General's Office, as distinct from its several posts in the field, contained as a separate line item a request for "Medical Books for Office, \$150."²

A first catalog of 1840 indicates that the Library of the Surgeon General's Office contained about 200 volumes. In the years before the Civil War the Library continued in its fairly languorous ways. Budget requests for binding, and for repair or construction of bookcases, are noted from time to time. Occasional exchanges or gifts were offered:

John Kearsley Mitchell of Philadelphia sent copies of his book *On the Cryptogamous Origin of Malarious and Epidemic Fevers* (1849), and Daniel Drake sent a copy of his *Principal Diseases of the Interior Valley of North America* (1850). The Library moved with the Surgeon General, from place to place, and in the spring of 1862 wound up in the front parlor of a small building next to the Riggs National Bank. A printed catalog of 1865 shows 2,000 volumes on hand, including 67 periodical titles.

The Billings Era

In 1865 John Shaw Billings arrived on the scene. He had been graduated from the Medical College of Ohio, in Cincinnati, in 1860. When, on his 23d birthday, the guns fired on Fort Sumter, Billings took the examination for admission to the Medical Corps of the United States Army. He served at Chancellorsville and Gettysburg and in other major campaigns. Then, on December 31, 1864, he was assigned to duty at the Surgeon General's Office in Washington. Sometime in the fall of 1865 the Surgeon General's Library came under Billings's charge, and in 1867 Surgeon General Barnes asked Billings to devote "all his spare time" to medical bibliography and to development of the Library.

Billings's first and long-continuing task was to give major attention to acquiring materials for the Library's collections. He pored over dealers' catalogs; he organized a network of foreign agents and consular officers; he picked through booksellers' offers. He wrote to rural postmasters, asking them to turn over his desiderata lists to local physicians who might have copies of early journals. He advertised the Library's particular wants. He solicited gifts at home and abroad. He asked for books and journals, pamphlets and incunabula, hospital reports and doctoral dissertations, portraits and photographs. He was constantly on the prowl in the libraries of friends, as Oliver Wendell Holmes would later testify.

That he was successful can be illustrated by the three-volume catalog of 1873-74, which listed 50,000 titles. The Library had suddenly become the largest medical library in the country, twice as large as the next largest, the Library of the College of Physicians of Philadelphia. And all of this had been accomplished in less than a decade.

After this catalog appeared, Billings switched to a plan for printing the catalog serially, bringing it out in successive alphabetical segments and incorporating subject entries for periodical articles as well as for books; in 1876 he published his *Specimen Fasciculus of a Catalogue of the National Medical Library*, and on this plan, somewhat modified, the great *Index-Catalogue of the Library of the Surgeon General's Office*

would begin appearing in 1880. Please note that phrase, "National...Library." Printed forms used in the Library during the 1870s also bear that caption; the Surgeon General, as well, uses the phrase in his correspondence and *Annual Reports*.³

The first series of the *Index-Catalogue* appeared in 16 annual volumes, A through Z, from 1880 to 1895, and then another series was begun. Entries were duplicated and then printed in the monthly *Index Medicus*, in a classified arrangement, beginning in 1879, and that first annual volume indexed about 20,000 articles. Thus was provided a bibliographic service for current awareness, along with another service designed primarily for retrospective search, and so was launched the great bibliographical publication tradition of the Library.

Books and journals continued to pour into the Library. While Billings would on occasion grouse that "the proportion of what is both new and true is not much greater in medicine than it is in theology," his aim was to obtain every new medical work, great or small, in all languages, as soon published. More shelves were constantly pressed into service.

After the war the Government had taken over the old Ford's Theatre of tragic memory. In 1867 the Library was installed on the second floor of the remodeled Ford's. The Army Medical Museum and the Record & Pension Division were on the floors above and below. But the capacity of that facility was soon exhausted, and in 1880 Billings began concerted efforts to obtain a new and fireproof building. He asked for \$250,000; in 1885 Congress appropriated most of that sum; and in 1887 the new red-brick building was opened. It was located on the south side of the Mall, next to the Smithsonian, and comprised about 48,000 square feet of space. The Record & Pension Division was on the first floor, the Museum occupied the east side of the second floor, and the Library was installed in the great hall at the west end of the second floor. The huge self-supporting integral cast-iron book-stacks rose on three levels in the north half of the hall, and 45 feet above the Library floor an extensive bank of clerestory windows admitted light which filtered down through the cast-iron gratings of the stack levels to the shelves below. There was no artificial illumination of any kind, except for gaslight in the offices along the central corridor.

In the new building, the Library staff size grew from fifteen to twenty-two. In 1876, Dr. Robert Fletcher came on board as a contract surgeon at \$1,800 per annum, plus quarters allowance, to edit the *Index Medicus* and *Index-Catalogue*, and he stayed at the Library for 36 years. In 1891, just out of college, Fielding H. Garrison joined the staff, at \$1,000 per annum; he would publish his famed *Introduction to the History of Medicine* in 1913, and remain in harness at the Library until 1830.

Billings left Washington in 1895 and became Director of the newly forming New York Public Library. The Surgeon General's Library then held over 100,000 titles; an estimated 5,000 readers visited the Library every year; 2,000 reference queries were answered by mail; and books were lent to libraries and to out-of-town physicians who were willing to place a deposit of funds with the Library. In 30 years Billings had created the largest medical library in the world, and had furnished it with bibliographical keys of comparable magnitude.

The Middle Years

Over the period of the next 40 years, eleven different medical officers gave direction to the Library; only two of them served extensive terms in office, Colonels McCaw and McCulloch accounting for the years 1903-1919 between them. The first woman joined the staff in 1905, and by 1934 women held the majority of staff positions. The Army Medical School, having moved in in 1893, moved out in 1910; during World War I, medical training films were being made in the basement of the building. The Pension Division didn't move out until 1918. Some of the old Library hands departed, some hung on; there was a Civil War veteran still on the staff in 1919. The decades took their toll on the building; the wooden floors of the corridors were replaced with concrete, and new stack ranges were added. By the nineteen-thirties, the acquisitions budget, which had reached \$19,000 per year following the war, dropped to \$14,000, and all of that sum had to be allotted for journals, even though the subscription list dropped from 2,000 to 1,600 titles; over a period of two years only sixteen books were purchased. In those years the Library staff had thirty members, and their salaries totalled about \$60,000.

At this juncture, the Library celebrated its 100th anniversary. The reading room was cleared, folding chairs were put in place, and a large audience — ambassadors, military attaches, librarians, medical officers, private physicians, and many representatives of organizations abroad — assembled to hear an oration by Sir Humphry Davy Rolleston, past-president of the Royal College of Physicians of London. The newspapers reported that Sir Humphry "could hardly be heard beyond the fourth row," but the occasion certainly helped to bring both the achievements and the problems of the Library to the attention of the public and the Congress.

The newly appointed Librarian of the Army Medical Library was Colonel Harold Wellington Jones. One month after coming on the scene he wrote to the Surgeon General that "there is literally not an inch of room for expansion anywhere in the entire building except for a dirty old

coal hold that is unspeakable. . . We need the whole place cleaned, we need a lot of paint and electric wiring on the inside, we need varnishing, we need workers to go over the books and treat the bindings, we need people with vacuum cleaners, we need all the floors gone over, we need new linoleum. . . we need new furniture. . . and many other things."

So Colonel Jones rolled up his sleeves, and the Library's renaissance began. With the considerable help of Dr. Atherton Seidell, a retired biochemist and friend of the Library, he set up a microfilm service, and established a weekly bulletin announcing new journal issues, called the *Current List of Medical Literature*. When World War II came along, Colonel Jones saw to it that the early works in the collection were ferreted out of their various locations on the shelves and shipped to safe quarters in Cleveland, where a History of Medicine Division was established, and a rebinding program was begun under the care of Jean Eschmann. Perhaps most importantly, Colonel Jones persuaded the Surgeon General to invite the American Library Association to sponsor a formal survey of the Library, which was financed by the Rockefeller Foundation. The surveyors were Keyes Metcalf and Andrew Osborn of Harvard, Janet Doe of the New York Academy of Medicine, Thomas Fleming of Columbia, Mary Louise Marshall of Tulane, and Quincy Mumford, then of the New York Public Library. Their landmark report⁴ was published in 1944; it was titled *The National Medical Library*, and it furnished the basis on which the Library's future course was to be plotted.

Prominent among the surveyors' recommendations was the charge for total recataloging of the Library's collections and the establishment of a card catalog. The Library had belatedly begun such a catalog in 1916, formed of an amalgam of printed cards, manuscript cards, and cards on which had been pasted clippings from the *Index-Catalogue*. It was incomplete, inconsistent, and inordinately difficult to use. There was no shelflist. There was really no systematized scheme of shelf classification for books, and there were no exterior bookmarks to facilitate finding. There was no subject approach to recent books, except by sifting through the massive unprinted backlog files of the *Index-Catalogue*, by that time covering almost two million entries, and listing them under a single subject only.

The surveyors recommended changes in the Library's administrative and organizational arrangements, augmentation of the Library staff, and development of comprehensive budget management. It is an incredible fact that formal divisional organization had not been introduced into the Library until a month before Pearl Harbor. Divisional alignments were shuffled and reshuffled as the staff which then numbered about sixty was just about quadrupled over the next seven years. And the surveyors

declared, in capital letters, that a new building was an ABSOLUTE necessity.

The question of a new building had been up in the air for a long time. As early as 1918, Surgeon General Gorgas had put forward a plan to build a new structure on the Mall, and physicians throughout the country endorsed the project. But then a debate began on location, and the upshot was that in 1919 Congress appropriated \$350,000 for purchase of land contiguous to Walter Reed Hospital "for the final location of the . . . Museum, . . . Library, . . . Army Medical School." That was as far as the matter went, but a large painting of the proposed Library hung on the wall of the Surgeon General's Office for more than thirty years thereafter.

Even before this, in Billings's time, the sponsorship of the Library had been questioned. Proposals for transferring the collections to the Library of Congress were made as early as 1885. Such a proposal was again made in 1897, and there were similar murmurings in 1905. In 1915 transfer to the Library of Congress was incorporated into the language of the Army Appropriations Bill, but the provision was deleted at the last minute. In the thirties there was some talk of housing the Library in the new Library of Congress Annex, then being built.⁵

Then in 1930 the Public Buildings Commission notified the Army that the Library and Museum must vacate their home on the Mall as soon as possible; the old building would have to be torn down because it did not fit into plans for Mall development. To prepare for the eventual move the Surgeon General had preliminary building drawings made, but President Hoover postponed the plan because of the large national budget deficit. In the summer of 1933, Surgeon General Reynolds asked the Library's Major Edgar Erskine Hume to get in touch with Dr. Harvey Cushing. Cushing had the ear of President Roosevelt, and over several years Cushing and the President exchanged notes. In 1938 the President told the Surgeon General to prepare legislation. Within months, Congress passed a bill authorizing \$3,750,000 to construct a new building for the Library and Museum, and in 1940 \$130,000 was appropriated for the preparation of plans. The architectural firm of Eggers & Higgins was hired, and it drew up preliminary plans numbered through Scheme K before its contract was canceled because of the onset of war. Once more the building project had expired.

In 1946 Surgeon General Kirk appointed Colonel Joseph H. McNinch to be Director of the Army Medical Library, in addition to his primary duty as editor-in-chief of the medical history of World War II. There had been disagreements among the top officers of the Library, often dividing along lines of conservatives versus reformers; there were some ugly tensions among the burgeoning staff. The split administration

between military Director and civilian Librarian, as mandated by the Survey Committee, did not seem to be working out. General Kirk instructed Colonel McNinch to find solutions to these problems, and to advise him on the future direction of the Library.

Colonel McNinch listened to his division chiefs, and judiciously sorted out the issues. He placed emphasis on development of the photoduplication section, and he bolstered the faltering *Current List* as the Library's basic current bibliography. He was dubious about continuation of the old *Index-Catalogue*, which had been in question since Colonel McCulloch's time; he asked the Surgeon General to appoint a special Committee on the Indexes Published by the Army Medical Library, and to authorize a project at the Welch Medical Library as the research arm of that Committee. He decided that a young medical officer should be sought as the new Director, who would obtain a formal degree in librarianship, and who would be exempted from the conventional four-year rotation to a post outside of Washington; recruitment was begun shortly thereafter.

Above all, Colonel McNinch thought long and hard about the need for a new building, about choice of a site, so long disputed, and about sponsoring agency; he realized, more than most, the intricate interrelationships among these factors. He considered the possibility of an option which would declare the Library a civil function of the Army, thus granting it a semi-autonomous status. He came to believe in the need for legislation to establish unequivocally the Library's role and place in the Government. He shepherded his convictions through the corridors of the Pentagon, before the Hawley Board and the Armed Forces Medical Advisory Committee.

In 1947 the Army Medical Museum proper moved out to a temporary building nearby; its parent Institute of Pathology remained. But the acquisition by the Library of the Museum's large second-floor hall gave temporary respite, and furnished room, though soon filled to bursting, for the Library's growing technical services component. Other Library elements were eased into temporary buildings across Independence Avenue. In 1948 the building's one and only elevator was constructed against the outside wall of the west block, finally affording a means of conveying loaded book trucks from floor to floor. It was not until 1955, after the Armed Forces Institute of Pathology moved to new quarters on the grounds at Walter Reed, that the Library finally occupied the entire building, relocating every volume in the entire collection and finding just enough breathing space to last the final lap.

The Final Lap

Fresh from library school, I became Director of the Library in October 1949, at a time when the Department of Defense had just been created. The Secretary of Defense in 1950 requested that the National Research Council establish a committee on the Army Medical Library, to consider the proper location of the Library in the government structure. The Committee, under the chairmanship of Dr. George Corner, in 1951 made its recommendation that "the Army Medical Library should continue to be operated as a National Medical Library under the administration of the Department of Defense," that, as an alternative, transfer of the Library to the Public Health Service should be considered, and that in any event specific authorizing legislation should be drawn up. In 1952 the Secretary issued a directive designating the Library the Armed Forces Medical Library, a joint agency of the three military departments, budgeted for by the Army, to function as "a central or national library."

In early 1955 a subcommittee of the Task Force on Federal Medical Services of the second Hoover Commission (on Organization of the Executive Branch of the Government) released its report recommending that the Armed Forces Medical Library be reconstituted as the National Library of Medicine, functioning as a semi-autonomous agency under the Smithsonian Institution. The chairman of that subcommittee was Dr. Alan Gregg, and one of its members was Dr. Michael DeBakey, who had long demonstrated his intense interest in the Library. Dr. Worth Daniels, a prominent Washington practitioner who had served as president of the Society of Medical Consultants to the Armed Forces, had also closely involved himself in this issue. These three physicians — Gregg, DeBakey, and Daniels — along with many others of their colleagues, over the years, deserve credit for their considerable roles in ensuing developments.

In the fall of 1955 Senators Lister Hill and John F. Kennedy began to develop language for a Library bill; after much rewriting, in March 1956 Senator Hill introduced his bill which would convert the Armed Forces Medical Library to the National Library of Medicine, to function as an independent agency of government. Following hearings before a Senate subcommittee, the bill was redrafted to provide for transfer of the Library to the Public Health Service, and in June 1956 the Senate passed the bill in that form.

A diversion then ensued, as bills were introduced in the House which were identical to the Hill-Kennedy bill, except for specifying Chicago as the site for the Library's new building. A compromise was eventually reached which left moot the question of site, but assigned the power of site selection to the nascent Board of Regents. The bill as

amended passed the House in July 1956, and was concurred in by the Senate on the following day. President Eisenhower signed the National Library of Medicine Act into law on August 3, with its provisions to go into force on October 1. After forty years of struggle, in the event it turned out that the final package was delivered in less than six months. Appropriations for the new Library building came in 1958. As Senator Hill liked to say, "nothing is ever settled until it's settled right."

Meanwhile, back at the old red brick on Independence Avenue, programs were being modified and redirected. The most important of these involved the decision to discontinue the *Index-Catalogue*, made and concurred in in 1950⁶; the final volume of the fourth series appeared in 1956. The *Current List* was revamped into a monthly publication with annual cumulations, and in 1960 a new publication process was inaugurated, involving an ingenious complex of punched cards, tape-oriented typewriters, and an automatic camera which photographed 300 multilined entries per minute. Besides affording vast improvement in the immediate management of the project, the new system was important for two additional reasons: it made possible the transfer of the *Index Medicus* title back to the Library after its thirty-year sojourn with the American Medical Association, and it provided a base on which a more complex and versatile system could be developed. I have treated these matters in more detail elsewhere.⁷

In 1958, according to a new and revised count, the Library collection included more than 1,000,000 items. During most of this period the Library staffing level hovered around 210-220, with appropriations of about \$1,500,000. Estelle Brodman ran the Library's public services, Ruth MacDonald was in charge of cataloging, Samuel Lazerow looked after acquisitions, and Seymour Taine supervised indexing operations. In 1960 Scott Adams rejoined the staff as Deputy Director, after a ten-year hiatus; he had been Chief of Acquisitions and Acting Librarian at the old Army Medical Library between 1945 and 1950.

In 1958 the architectural firm of O'Connor & Kilham, of New York City, was hired, and building planning entered an intensive stage. Keyes Metcalf acted as building consultant, and contributed a great deal, particularly in the direction of simplifying stack layouts. We did have some fights with the Bureau of the Budget, including a very tough one over the number of square feet to be allowed, finally set at precisely 232,000; the last 8,000 square feet that were eliminated undoubtedly cost more not to build than they would have cost to build. The site was the old golf-course adjacent to the south edge of the National Institutes of Health reservation, and groundbreaking took place in June 1959. The design called for underground stack levels, involving major excavation; this later led to serious delays in the building schedule, when hard rock was encountered

where 'rotten rock' had been expected. But by December 1961 the building was 90% completed; the main entrance, central catalog area, and main reading room were clear and ready, so we went ahead and held the dedication ceremony while the cement was still drying elsewhere in the building. These circumstances were responsible for some snide remarks in the local press on the state of building incompleteness; but I was not about to consider postponement, when I knew that mounted at the entrance was a block of black marble with incised letters saying that the Library "was established on this site in 1961, the 125th anniversary of its founding."

The year 1961 was a banner year in several ways. The first issue of the annual *Cumulated Index Medicus* was published; the third and last volume of the fifth series of the *Index-Catalogue* appeared, after 80 years finally winding down that great work in a total of 61 volumes; and a contract was signed and work begun on the MEDLARS® project, the Library's venture into computer-mediated bibliography. The final move to Bethesda was not completed until April 1962, and by spring 1963 both the MEDLARS computer and the spectacular Wildenhain ceramic mural had at last been installed. A scion from the original Hippocrates plane tree on the island of Cos was planted and replanted, and soon took hold; its subsequent growth may serve to gauge the splendid development of the Library since those far-away times.

"Inevitability," says one of our most prominent historians, "is an attribute that historical events take on after the passage of sufficient time. Once the event has happened and enough time has passed for anxieties and doubts about how it was all going to turn out have faded from memory, the event is seen to have been inevitable. . . . Before long what did happen appears to be pretty much what had to happen."⁸ Maybe the heroic age of Billings, and events like the move to the old red brick building just 100 years ago, are far enough away to take on in dreamy retrospect the appearance of inevitability. Yet today when we look back to a time only 50 years ago — at Colonel Jones carrying in his own oriental rugs to decorate the dais at the Library's centenary celebration, for instance — we may be reasonably sure, close as we are, that neither Jones nor his successor generations have been afforded the luxury of entertaining any such view.

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A Brief Recent History of the National Library of Medicine

Martin M. Cummings

I am pleased to have been invited to review the recent history of your National Library of Medicine. My remarks are based on events described in the Annual Reports of the National Library of Medicine and the transactions of its Board of Regents for the years 1964-1984. These sources were used to reinforce my memory in identifying events, people and dates and to reduce bias. However, I cannot resist sharing some unrecorded key events — unrecorded either to avoid embarrassment to those involved or to spare my own hide from lashes, which might have been applied by those whose political or administrative orders I either ignored or subverted. Accepting the invitation to address you today provides an opportunity to review the accomplishments of my colleagues. This will be my main purpose.

No one assumes responsibility for leadership of a well established institution without recognizing the contributions of those who preceded in the establishment and growth of the organization. NLM was blessed with the genius of John Shaw Billings as its founder, the early interest of Colonel Joseph McNinch in mechanization, and the creativity and foresight of my immediate predecessor, Dr. Frank B. Rogers. From Brad Rogers we inherited a magnificent new library building, a great collection of medical books and journals, the design, installation and early testing of MEDLARS and several remarkable staff members whose contributions sustained library excellence in its services and operations for many years. Noteworthy in this context were Scott Adams, Deputy Director; Dr. John Blake, Chief of the History of Medicine Division; Mrs. Thelma Charen, Head of the Indexing Section; and Mr. Charles Roos and Mrs. Dorothy Hanks, research reference librarians. Mrs. Charen continues her work as the world's greatest medical indexer for more than 40 years. Mrs. Hanks continues to provide outstanding services to the scholarly community. Foremost in this inheritance was Scott Adams, my teacher, counselor and principal link to the medical library community, many of whom were disappointed by the appointment of a non-librarian as Director.

It was not long before I discovered that the governance of the Library was shared with a remarkable policy setting body, the Board of Regents. Established by statute with its members appointed by the Presi-

dent, the Regents provided sound advice and counsel throughout my tenure. They were not only supportive of NLM programs but were creative as well as analytic in performing their duties. Two physicians were appointed to the Board by two different Presidents. They were Dr. William N. Hubbard, Jr. and Dr. William Bean. Dr. Hubbard, who was appointed to the Board in 1964, was elected to serve as its Chairman three times. Nearly all Board members were involved actively in major library planning and policy determinations.

Regrettably there was an impasse between the administration and the Senate concerning Board appointments during the Nixon presidency. Efforts to politicize the Board led the Senate to withhold confirmation of all nominees until, at one point, only one appointed member, Dr. Joseph Volker, President of the University of Alabama at Birmingham, remained. He carried out the work of the Board, assisted by all of the ex-officio members representing various government agencies. The problem was resolved in 1978 when the NLM statute was changed to having appointments made by the Secretary of the Department.

My principal goals for the National Library of Medicine were to complete the MEDLARS system designed by Rogers, to develop an intramural research program in the field of biomedical communications, and to establish an extramural granting program in the mode of the National Institutes of Health. I was encouraged to give the highest priority to the grants program by Scott Adams, Surgeon General Luther Terry, and the Board of Regents.

Without adequate legislation the Library was unable to implement the extramural program plan developed by Scott Adams and Estelle Brodman. The Library, therefore, requested a legal opinion asking whether the Public Health Service Act could be used for this purpose. On March 3, 1964, the Comptroller General of the United States ruled that some provisions of the Public Health Service Act could be employed to make grants for the support of limited biomedical communication activities. A Publications and Translations Division and a Research and Training Division were consequently created to formalize the beginning of the National Library of Medicine's extramural program. In March 1964, Mary Corning, an outstanding science administrator at the National Science Foundation, joined the staff to develop and manage this activity. Dr. Marjorie P. Wilson was recruited from the NIH as Associate Director for Extramural Programs at the same time. They developed the comprehensive programs which were the basis for a highly successful rejuvenation and transformation of medical libraries in this country.

In 1964, Dr. Michael DeBakey, Chairman of the President's Commission on Heart Disease, Cancer and Stroke, was developing plans for the creation of Regional Medical Programs. As a former member of the

Board of Regents, he knew the needs of medical libraries and invited us to develop the rationale for including a regional library network as part of the proposed regional medical system. He also encouraged us to use his report to justify the creation of extramural as well as intramural library research and development programs.

At the same time discussions with Senator Lister Hill gave me further encouragement to seek legislative authority to implement broad-based programs. In October 1964, Dr. Stafford Warren of the President's Commission on Mental Retardation issued a report calling for the development of a university-based national system of libraries utilizing MEDLARS as a prototype information system. This recommendation, associated with the report of the President's Commission on Heart Disease, Cancer and Stroke issued in December 1964, provided a powerful expression of public support for a program of grants and contracts to improve medical library services in the United States.

On January 19, 1965, the Medical Library Assistance Act (S. 597 and H.R. 3142) was introduced in Congress by Senator Lister Hill and Representative Oren Harris. Our friend, Representative John E. Fogarty, introduced an identical bill (H.R. 6001) on March 19, 1965. Hearings were held in the Senate in June 1965 and in the House shortly thereafter. Professional medical societies joined the library community in providing strong testimony supporting the legislation. It passed with an overwhelming majority even though it was opposed by the Bureau of the Budget.

In June 1965, NLM organized the John Shaw Billings Centennial honoring its founder. The occasion was used not only to chronicle Dr. Billings's contributions to libraries and public health but also to attract public interest in the Library's future as a national center for biomedical communications. We were encouraged to take the necessary actions to make the Library an active information processing center rather than a passive repository of books and journals.

The acceptance and growth of new functions which accompanied the introduction of new technologies required the creation of several new senior positions to assume responsibility for planning and managing various new NLM operations and services. Dr. Joseph Leiter was recruited as Associate Director for Intramural Programs in 1965.

MEDLARS

The full implementation of MEDLARS was delayed by the contractor's inability to meet deadlines. The Library was unable to generate *Index Medicus* by computer in January 1964, as planned. The major delay was due to problems with the computer-driven photocomposer. Finally,

the graphic arts composing equipment, GRACE, was delivered in June 1964 and was used to produce the August issue of *Index Medicus*. GRACE served as a useful apparatus for all NLM computer-generated publications for almost a decade thereafter.

Although MEDLARS was designed with a well controlled thesaurus, rapid advances in biomedical sciences outraced its scope. This problem of an inadequate vocabulary was exposed during the first year of MEDLARS operation. The weakness in the medical subject headings was attacked promptly through the recruitment of Dr. Peter Olch, a highly qualified scholarly pathologist working at the National Institutes of Health. He set in place the mechanism through which the structured nomenclature could be enriched and elaborated to facilitate better search and retrieval. This effective system, which involved bringing experts into the Library from various areas of the rapidly advancing field of medicine, was further augmented by the subsequent excellent work of Dr. Norman Shumway and Dr. Clifford Bachrach.

It soon became evident that the batch mode of responding to search requests did not provide timely responses to the users. Although the decentralization of MEDLARS to the University of Colorado and UCLA in 1965; to Harvard, the University of Alabama, and the University of Michigan in 1966; and to Ohio State University, the Texas Medical Center, and the National Institutes of Health in 1967, improved the system's overall performance, it was apparent that planning should take place immediately for upgrading and improving the efficiency of MEDLARS. The problem was simply that increased demands for services provided new stresses which degraded the system's performance.

We engaged F. W. Lancaster in December 1965 to evaluate the performance of MEDLARS. He was aided by an Evaluation Advisory Committee of Federal and non-Federal experts to assure impartiality. This was the first large scale evaluation of any computer-based information system. The seminal report of that evaluation, issued in January 1968, revealed that the system was operating with 58 percent recall and 50 percent precision. Recall and precision are strongly interconnected in an inverse relationship. The findings were based on user evaluation of search performance, and, since no other operating information system had undergone such a performance evaluation, we had no basis for comparison. It appeared, however that the greatest potential for improvement in MEDLARS existed at the interface between the user and the system. The deficiencies which were identified in the indexing process had already been greatly improved through the development of expanded subheadings and the introduction of new scientific vocabulary. Also established was an external group of experts, who reviewed the quality of journals selected for *Index Medicus* and MEDLARS. These actions led

to greater user satisfaction and subsequently a rapid increase in demands for service. In addition, libraries were assisted in acquisitions and cataloging by our publication of the *National Library of Medicine Current Catalog*, one of the first major completely automated recurring book catalogs.

The original objectives established for MEDLARS by Dr. Rogers in 1961 were largely met by 1966. These included the improvement of the quality and scope of *Index Medicus*, while at the same time reducing the time required to prepare monthly editions for printing from 20 days to 5 days. Also, it made possible the production of specialized bibliographic compilations for the biomedical community. The intellectual effort required for the development of recurring bibliographies proved to be a much more difficult task than estimated originally. The average depth of indexing per article was increased by a factor of 5, i.e., 10 subject headings instead of 2. The major medical journals were indexed in greater depth and more rapidly than journals which were judged to be less significant.

However, MEDLARS failed to meet fully the objective of making possible the prompt and efficient servicing of requests for individualized bibliographies, both on demand and on a recurring basis. The objective called for a maximum of two days to produce such bibliographies. In fact, the average time was two weeks. This observation more than any other led to the determination to redesign the MEDLARS system through the upgrading of its computer hardware and through improving the state-of-the-art with more sophisticated software capabilities. In 1967, MEDLARS II was planned to achieve the following:

1. Online augmented MeSH[®] vocabulary.
2. An automated acquisitions and cataloging system.
3. Online indexing and searching.
4. A graphic image storage and retrieval system closely linked to the MEDLARS computer search capability.
5. A drug literature program with chemical search capabilities added to MEDLARS.
6. A toxicology information exchange.
7. The training of staff and users to operate the system effectively.

It is pleasing to recall that these goals and objectives set forth in 1967 were largely met by 1971. Credit for this should be given to Dr. Joseph Leiter for the bibliographic systems achievements, to Dr. Henry Kissman for the accomplishments associated with the Toxicology Information Program, and to Dr. Ruth M. Davis for the initiation of an innovative and highly creative research and development program which led to the development of MEDLINE[®], MEDLARS online.

New Responsibilities

In July 1967, the Public Health Service Audiovisual Facility located in Atlanta, Georgia, was transferred to NLM and was renamed the National Medical Audiovisual Center (NMAC). NMAC was challenged frequently as a government activity which should have been carried by the private sector, but it failed to flourish. On April 1, 1968, the Library, which had been a Bureau in the Office of the Surgeon General, was made part of the National Institutes of Health. This controversial move ultimately had a stabilizing effect on NLM budgets and programs.

With the extramural program well established by a statute which over the years authorized \$105,000,000 for Library grants, we turned our attention to the development of an intramural research program. Before it was fashionable to offer top management positions to women, I had already learned that talented professional women can make dynamic and creative leaders. Both Dr. Marjorie P. Wilson and Mary E. Corning were recognized for their brilliant implementation of domestic and foreign library and communications programs. Mary Corning's organization and documentation of a series of international meetings concerned with the development of a global MEDLARS network represents a sensitive and brilliant accomplishment.

NLM policy called for cooperation and assistance to other libraries at home and abroad as far as resources would allow. The extensions of MEDLARS services to other countries during the period 1966-1970 required extensive negotiations and technical assistance. Mary Corning was appointed Special Assistant to the Director for International Programs in 1967. She assisted in the development of a global medical library network, which ultimately involved the United Kingdom, Canada, Australia, Japan, Sweden, France, West Germany, Switzerland, Italy, Kuwait, Colombia, Egypt, China, and Mexico. She was a major contributor to the creation of a Regional Medical Library established at the Escola Paulista de Medicina in Sao Paulo, Brazil. Administered successfully by the Pan American Health Organization for two decades, this library has become the most important medical library in Latin America.

The National Library of Medicine has been actively involved with international affairs, contributing consultation and technical assistance to the World Health Organization, UNESCO, the Organization for Economic Cooperation and Development, and the International Council of Scientific Unions Abstracting Boards. In addition, it has assisted more than 60 developing countries through the provision of library loans, photocopies, duplicate books and journals, and specialized reference and bibliographic services. Approximately 20,000 such services were provided

annually until 1978, when a requirement for cost recovery became U.S. government policy.

Through formal government-to-government agreements the NLM developed and maintained special administrative and technical arrangements with the U.S.S.R., People's Republic of China, and Egypt. Through the use of special foreign currencies (P.L.480 funds) the Library supported productive and unique scientific publications and translations/programs in Israel, Poland, India, Egypt, and Yugoslavia. These activities expanded considerably and were ultimately transferred to Dr. Jeanne Brand, who has served as the extramural program officer for the past ten years. This program has been recognized as a valuable mechanism through which to disseminate foreign scientific information to the relevant American biomedical community.

The need to establish in-house competence in information research and development continued. We turned next to Dr. Ruth M. Davis, an applied mathematician in the Department of Defense, to become the first Associate Director for Research in 1967. Dr. Davis recruited a highly qualified staff of computer scientists and communications engineers. They developed a technical plan which called for the use of audiovisual facilities, satellites and online computer services for rapid distribution of medical information in support of research, education and patient care. We needed technical facilities and funds to implement this plan.

In 1968, the Library honored Senator Lister Hill on the occasion of his retirement after 44 years of legislative service. During the colloquium, his colleague from Alabama, Senator John Sparkman, announced that he would introduce a resolution calling for the construction of a new NLM research facility to be named the Lister Hill National Center for Biomedical Communications. We were invited to draft the language which Senator Sparkman used in the Senate and later in the House of Representatives. A Joint Resolution of Congress authorizing the program and the construction passed unanimously and President Johnson signed it into law on August 3, 1968.

In 1969, Scott Adams retired from the Library after a long and productive career in Federal service. He was replaced by Dr. G. Burroughs Mider, who came to NLM from his position as Director of Laboratories and Clinics at NIH, where he was responsible for the growth and development of the NIH Library, among other accomplishments.

In 1969, Dr. Davis was named first Director of the Lister Hill Center. With her associate, Davis McCarn, the first NLM online bibliographic retrieval system (AIM-TWX) was developed successfully by the Systems Development Corporation. This was refined and enlarged to become MEDLINE in 1971. At the same time the Lister Hill Center staff acquired access to a communications satellite (ATS-1) at no cost

and utilized it successfully for support of patient care in remote Alaskan villages. This program was expanded to provide educational services linking medical students in Idaho, Montana, and Alaska to the University of Washington in Seattle.

In 1970, the Library recruited Dr. Henry M. Kissman and several senior professional staff members from the Food and Drug Administration to develop the toxicology information program, which had been called for by the President's Science Advisory Committee in 1967. Their work led to the development of TOXICON (later renamed TOXLINE®) in 1971. TOXLINE has been a major source of information about the effect of drugs and chemicals on man and his environment. CHEMLINE®, an important chemical directory, was implemented by Bruno Vasta in 1972. These were the first of a series of specialized information data bases which were linked to the MEDLARS family of bibliographic data bases.

Dr. Harold M. Schoolman joined the NLM staff as Special Assistant to the Director in 1970. He has served as a most effective link to the medical education community since that time. His background in medical research, education and statistics provided valuable insights into user needs and served as a practical and philosophical base upon which the Library reached priority judgments.

Dr. G.B. Mider retired as Deputy Director in 1972 after providing effective leadership in planning and managing the internal operations of the Library for four years. Melvin Day was recruited as Deputy Director, a position in which he served with great distinction for seven years. Mr. Day was a pioneer in government-sponsored systems, having developed them for the Atomic Energy Commission and NASA. Like Dr. Mider, Mel was an excellent administrator and an articulate spokesman for NLM in the highest circles of government.

In 1973, the Library was blessed with the appointment of Dr. Ernest Allen as Associate Director for Extramural Programs. Dr. Allen was a founder of the NIH grants program after World War II and was widely applauded for his work as Associate Director for Research Grants at NIH and as Deputy Assistant Secretary for Grants and Contracts at DHEW. He provided a mature and stable leadership which kept the program viable during a period when obtaining renewal authority for the Medical Library Assistance Act was becoming difficult and funds for growth of the program were not forthcoming.

In 1974, MEDLARS II became fully operational, providing efficient online services from ten NLM-produced data bases. The number of users of the system grew rapidly forcing NLM management to introduce modest user charges to control explosive growth and to test the value of the service within a marketplace economy. Establishing a fee for serv-

ice did not reduce usage at this time nor did it when prices were raised subsequently.

During this period of rapid development, the Library was threatened with litigation by a major American book publisher because we refused to accede to their demand to pay a royalty for photocopying articles in the journals which they published. We argued that the "fair use doctrine," which allowed single copies of articles to be copied for research or educational use, applied in the case of the NIH Library and NLM. In November 1973, the full Court of Claims overturned that ruling. Williams and Wilkens appealed to the Supreme Court and on February 25, 1975, the Supreme Court ruled in favor of the Library in a split decision. In this important, protracted legal battle, NLM won the right for "fair use" photocopying not only for itself but for all libraries. The Director was supported in this exhausting battle by Mr. Albert Berkowitz, Chief of Reference Services and Dr. Harold Schoolman, Assistant Deputy Director. Great support also came from the American medical community and from librarians everywhere.

Although the Congress had authorized the construction of a new, ten story communications research facility in 1968, only planning and design funds were made available. The building was designed to include modern communications laboratories, an auditorium, audiovisual production facilities and offices in 200,000 square feet. Our requests for construction appropriations were given low priority by NIH and the Department of Health, Education and Welfare or were disapproved by the Bureau of the Budget. Greatly disappointed by this lack of support, members of the Board of Regents and I undertook discussions with Congressmen Paul Rogers, Daniel Flood and Robert Michel as well as Senators Hubert Humphrey, Warren Magnuson and Norris Cotton.

Concerned by my slow recovery from a myocardial infarction and disappointed by the lack of funding for the construction of the Lister Hill Center, I decided to retire after 30 years of government service. While some of my friends and colleagues were collecting money for a surprise farewell dinner and gift, the Congress appropriated \$26 million in January 1976 for construction of the Lister Hill Center. This action had a powerful therapeutic effect and I cancelled my retirement plan, causing great embarrassment to those who were making arrangements and had to return money to friendly and generous donors.

Although the Bureau of the Budget withheld release of the funds for more than a year, we succeeded in awarding a construction contract in 1977. Through careful administrative management by Kent Smith and with technical support from Ross Holliday, Head of Engineering Services at NIH, the building was completed near schedule and under budget. It was dedicated on May 22, 1980. The total cost of construction and

equipment came to \$21 million, leaving approximately \$5 million to be returned to the Treasury. The Appropriations Committees were so pleased with this performance they allowed us to keep the surplus which was used to renovate and refurbish the Library building, which was then 20 years old. This was done effectively under the careful guidance of Ken Carney, Executive Officer.

Nineteen hundred and seventy-six provided us with an opportunity to inform the nation about our services and accomplishments as part of the U.S. bicentennial celebration. An excellent report entitled, *Communication in the Service of American Health*, was prepared by Robert Mehnert. In addition, a two-day symposium co-sponsored by the Macy Foundation led to the publication of a highly esteemed two-volume history of American medicine entitled, *Advances in American Medicine: Essays at the Bicentennial*. Mary Corning organized the program for this important occasion.

In 1977, Emilie Wiggins completed a massive restructuring and modernization of the *NLM Classification*, the major medical library guide to collections used throughout the world.

In 1978, we lost our outstanding Deputy Director, Melvin Day, who was appointed Director of the National Technical Information Service. Mr. Day introduced management methods appropriate to the rapidly developing field of information science and was an excellent representative to domestic and foreign library and information associations.

In 1979, the NLM appointed Kent Smith as Deputy Director. He was the first professional administrator selected for the position, which was previously filled by librarians or biomedical scientists. NLM had for many years served as a breeding or training ground for outstanding administrative and executive officers. Among the individuals trained were James Isbister, who became Administrator of the Alcohol, Drug Abuse and Mental Health Administration; George Russell, presently Director of the NIH Division of Management Policy; Edward McManus, Deputy Director of the National Eye Institute; Philip Amoruso, Director of the Office of Administrative Management at the National Cancer Institute; and Kenneth Carney, presently NLM Executive Officer.

In 1979, we celebrated the Centenary of *Index Medicus* with a program which brought scholars and historians together to review programs in bibliography, publishing and medicine for the past century. The papers presented were compiled and edited by Dr. John B. Blake and were published by NLM in 1980. In the same year, Dr. Clifford Bachrach was appointed editor of the (3rd series) *Index Medicus* and served effectively in this capacity for the next six years.

Nineteen hundred and seventy-nine also introduced the first public access online catalog system (CITE) developed by the Library's Dr.

Tamas E. Doszkocs. This led to the decision to begin the retrospective conversion of the massive public card catalog to a machine readable format, a task which was successfully completed within five years. Another significant advance in library software was the Integrated Library System, developed by Mr. Charles M. Goldstein, which is now in use in many libraries throughout the country.

The Eighties

The dedication of the Lister Hill National Center for Biomedical Communications took place in May, 1980. Distinguished leaders of science, education and medicine joined to pay tribute to retired Senator Lister Hill, who was able to attend. He was intellectually vigorous and alert, even though confined to a wheel chair. Congressman Paul Rogers, who was most helpful in securing the building appropriation, also attended. A major scientific program which described advances in communications technologies was held on this occasion.

In 1981, MEDLARS delivered 2 million online and off-line searches. This phenomenal success was accompanied by a series of attacks by the Elsevier Publishing Company, a large Dutch firm which produces *Excerpta Medica*, a bibliographic product that its publishers see as a competitor to *Index Medicus*. They engaged an American law firm to lobby against NLM interests and the Library was forced to respond to a series of confrontations and debates to keep the record straight. Their objective was to force NLM to cease providing online bibliographic services. The lawyers, who were registered foreign agents, provoked several special studies and inquiries, one by the Congressional Office of Technology Assessment and another by the Department of Health and Human Services. In both cases the findings supported NLM's continued provision of online information services under a policy of recovering the costs of dissemination, although not the costs of indexing and cataloging, since these functions were performed as a necessary element of library operations.

Also in 1981, with the advice of the Board of Regents, we implemented a program to support research and training in medical informatics using grants and contracts. At that time NLM was the only federal agency devoting significant resources to this important new field.

Culminating several years of effort by the Technical Services Division, the public card catalog was closed in 1981 with the full implementation of CITE for online access to the catalog following in 1982. NLM was one of the first large resource libraries to accomplish this conversion. At the same time the Library implemented the National Serials Holding Database (SERHOLD®), developed by Betsy Humphreys and others,

which now provides information in serial publications held by more than 2000 libraries.

In 1982, the Library noted the tenth anniversary of MEDLINE. The modest network established in 1972 had expanded to more than 1800 U.S. institutions at which more than 2 million searches were being conducted annually. The databases contained more than 4 million references and approximately half of the articles cited included abstracts.

Nineteen hundred and eighty-two also produced two significant publications sponsored by NLM. Seven years of research by Dr. Wyndham D. Miles culminated in the publication, *A History of the National Library of Medicine: The Nation's Treasury of Medical Knowledge*. This book chronicles the creation and evolution of NLM in a scholarly and highly readable style. It represents the most comprehensive history of the National Library of Medicine from 1836 to 1976.

The second major publication was entitled, *Academic Information in the Academic Health Sciences Center: Roles for the Library in Information Management* by Nina Matheson and John A.D. Cooper. The study was performed by the Association of American Medical Colleges under a contract with NLM. It has led to a careful re-examination of how information services at universities may be integrated to better serve the needs of scholars, administrators, educators and students.

It should be noted that Dr. William G. Cooper served as Associate Director for Planning and later as Associate Director for Extramural Programs from 1979 through 1985. His previous experience as a professor and senior officer at the University of Colorado School of Medicine was extremely valuable in designing programs to serve the information needs of medical education and research.

In 1983, the MEDLARS III Request for Proposal was issued after deliberate and protracted planning by Joseph Leiter, John Anderson and many others. The local area network was installed in the Lister Hill Center and the renovation of the library building was completed.

Finally, it needs to be noted that a broadly based research program, involving the sophisticated application of micro and minicomputers, has contributed to the development of artificial intelligence for expert medical systems. Research involving the use of video and digital optical discs as methods for preserving, storing and retrieving images and information have been initiated. Earl Henderson, Richard Friedman, James Woods, George Thoma, and William Harless have been particularly successful in providing leadership and stimulation for advances in this important new field of communications research and development.

A major problem in recruitment and retention of senior scientific and technical leadership has resulted from the relatively low salary scales in government as contrasted with industry and universities. Although

this has adversely affected the NLM in recent years, its impact on overall growth and development has been minimized through the use of contractor-assisted research support.

Several of the senior staff recruited 20 years earlier announced their intentions to retire. Mary Corning, Assistant Director for International Programs, retired after 34 years of Federal service. Dr. Joseph Leiter, Associate Director for Library Operations, retired after 45 years of Federal service. Their departure stimulated some reflection on my part.

During the past two decades, we exceeded our goal of providing more than \$100 million in support of our nation's medical library activities. The MEDLARS program had performed more than 10 million searches to the biomedical community in this country and overseas. It produced 236 issues of *Index Medicus* and 19 annual cumulations. Several thousand bibliographies were published to meet current medical interests. A substantial intramural research and development program was established in a modern, well equipped facility. The NLM budget, which was approximately \$3.6 million dollars in 1964, had increased to \$48 million in 1984. During this time the staff grew from approximately 220 to 490. The characteristics of NLM staff were broadened to include expertise and competence in many fields related to biomedical science, engineering, information science, as well as librarianship. The Library had strong new leadership with the appointment of Lois Ann Colaianni, Associate Director for Library Operations and Dr. Henry Riecken, Associate Director for Planning in 1982.

In exercising leadership, the Office of the Director had benefited from the unflinching support by the Board of Regents and the Office of the Surgeon General. Ex-officio members of the Board representing the three military services, the Veterans Administration, the National Science Foundation and the Library of Congress were influential contributors to the planning for NLM programs.

I stepped down as Director in October 1983 but continued to serve the international program in Mary Corning's position until a suitable replacement could be found. I retired on January 3, 1984, exactly 20 years after assuming the directorship.

Whatever success was achieved by your National Library of Medicine during these two decades is largely attributable to its early solid foundation, augmented by the dedicated and creative performance of new library staff, the sustained wise advice provided by the Board of Regents, the understanding and support from Congress, and the good will of the large community of physicians, scientists, educators and students we have been privileged to serve.

Continued successful development of the National Library of Medicine was assured by the appointment of Dr. Donald Lindberg as the

Director in 1984. A distinguished leader in the field of medical informatics, he brings to NLM the scientific, technical and administrative skills which are required to keep the National Library of Medicine in the forefront of information processing and knowledge transfer. I wish for him the same substantial, intellectual and financial support which I was privileged to receive during the previous two decades.

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Afternoon Session

Introduction

Donald A. B. Lindberg, M.D.

Director, National Library of Medicine

Because the speakers this afternoon were all involved in helping to develop the Library's Long-Range Plan, I wish to take a minute to describe that effort.

The planning process has taken one year, and finished on schedule. The five Panels did as they were enjoined, setting apart all previous Regents policies and to start anew by considering how the world will be 20 years from now and what role NLM should play in the future. The result is a plan we can be proud of. It will be presented to the Board of Regents tomorrow (September 17) for approval.

At the base of the Long Range Plan is the recognition that as information concerns become more obviously essential to modern science, the Library should play a central role in the most important efforts in biomedical research and health care. The National Institutes of Health remains at the center of such advances. This afternoon we are fortunate to have the Director of NIH, Dr. Wyngaarden, as our moderator.

Moderator: James B. Wyngaarden, M.D.

Director, National Institutes of Health

An organization's 150th anniversary is an apt occasion for celebrating accomplishments, spreading the word about current activities, examining roots (as we did this morning), and looking toward the future. Some may speculate rhetorically about great things to come, but I am pleased that the Library took a more pragmatic approach and examined carefully the options.

The plan that the Regents called for is not just a list of general goals and checkpoints for management, but a comprehensive plan that would involve all the various constituencies among the Library's users and enlist their support in achieving the envisioned future. Dr. Lindberg and his staff responded to this challenge with imagination. The planning in-

volved librarians, physicians, nurses, and other health professionals, basic biomedical scientists, computer scientists, and other groups whose interests and the NLM's mission coincide. Some one hundred experts and consultants participated in five planning panels established to deal with five specific domains of the Library. This afternoon's speakers all participated on those panels—four actually chaired their panels.

The speakers were not limited as to their choice of topic for today. They are free to discuss any aspect of the future of biomedical communications.

I should also mention that next month the National Institutes of Health will begin celebrating its one hundredth anniversary. Like the Library, we will be focusing on the past as well as the future, and dealing with a theme that will be exemplified here today—the theme of partnership between the worlds of academia, business, and government.

Ralph Waldo Emerson wrote, "the past instructs; the future invites." He might have added that the future invites especially those who have been well instructed by the past. Our speakers are all qualified not only by their accomplishments in a variety of disciplines, in medical as well as information fields, but also by their enthusiasm and realism in addressing the topic at hand.

The Library's Collection and Its Organization

Robert M. Hayes

Introduction

For a variety of reasons, I see my talk this afternoon serving both for its own purposes and as a bridge from the talks presented this morning to the others to come later this afternoon. Before focusing on the substantive issues that are the specific concern of my talk, therefore, I would like to comment on the transition.

First, and immediately relevant to the issues of my talk, is the fact that the library — any library, but especially the National Library of Medicine — is the institution whose central, characterizing function is the preservation of the record of civilization, and its collection is the embodiment of that responsibility. That means that the Library, in developing its collection, must always be concerned both with the past and with the future. That collection for the National Library of Medicine is the focal point of my own contribution here, and it is literally the bridge between the past and the future.

Second, one of the major substantive issues with which I will be concerned is the physical nature of that collection. Today, it is largely printed pages, in books, journals, manuscripts, and other forms. In the future, the range of media will certainly be far, far greater, with computer-based formats becoming increasingly important. But the transition from the past to the future, as I see it, will not be a revolutionary replacement of one medium by another, but instead will be a bridging of media, with all forms being significant to the collection and none replacing others except in very limited and specific ways.

Third, another substantive issue with which I will be concerned is the physical preservation of the collection, certainly an essential aspect of the preservation of the record of civilization. Today, the problems relate to the preservation of brittle paper. Clearly a bridge from the past to the future is the fact that technological media, such as optical disks, are seen as potential means for solving those problems. But those media themselves raise serious preservation issues, the resolution of which will similarly serve as a bridge from past to future.

Fourth, an underlying fact about the National Library of Medicine is that it has repeatedly served as a bridge from past to future, as a primary agent in bringing technological developments to operational reality. It

did so with respect to the development of what is now a vast array of indexing, abstracting, and other secondary access tools. The original *Index Medicus* was certainly among the first of the subject access journals, showing what was needed and feasible. It did so when it set specifications for high typographic quality in computer output at a time when the only generally available printers were "upper-case only" tabulators. That not only resulted in GRACE (Graphic Arts Composing Equipment), at the time the fastest computer-driven photocomposer in the United States, but by doing so demonstrated that computer composition was feasible. It did so when it distributed MEDLARS tapes and then contracted for the development of online services for access to them. The result was one of the first of such services and surely the first for which there was general public availability, but more than that it was the stimulus for creation of a new industry. Most recently, the NLM has again demonstrated its leadership in bringing new technology to operational reality by instituting a number of experiments in the use of optical disk technologies. In my view, these will become vital means for publication and distribution of information of all kinds — text, numerical data files, imaging. By its work, NLM has shown the technical feasibility of these methods and their importance to libraries. These all arose from the efforts by the NLM to provide the tools for organization and preservation of its collection, and they provided bridges from past approaches to the future ones.

Finally, it is important to note that a most significant long-term contribution of NLM has been in the development of the profession of medical librarianship. By its towering achievements, it has set an example which has led all medical librarians to aim for excellence; by its other contributions, only a few of which I've referred to, it has provided tools for the profession to achieve excellence. For many years NLM served as the place from which a generation of medical librarians gained their experience and commitment. And during many years, under the aegis of the Medical Library Assistance Act, the NLM has supported other programs to educate medical librarians, to provide internship experiences for them, to develop medical information systems analysts and researchers in medical informatics. The results are evident in the quality of information service in the field of medicine and they have provided the bridge by which the profession has moved forward. As we now move into the future, it is clear that NLM will continue this vital bridging role.

The Collection and Its Organization

Turning to the substance of my talk I must say that, in thinking about it, I desperately tried to find something new, but repeatedly I found myself returning to the results of the planning process which NLM

has just completed. As a participant in it, I found it stimulating and rewarding to visualize the future of this great Library. While it is difficult to make predictions, the process of doing so provides the definition of direction which may well make those predictions self-fulfilling.

My own responsibility in that process was as chair of Panel 1, concerned with the future of the collection at NLM and its organization. My talk will present the results from the deliberations of that group, the first of the planning panels convened by the National Library of Medicine for the purpose of considering issues related to long-range strategic planning for the NLM. In a real sense, the panel focused on the most central of the planning issues, the ones that make the Library what it is and that best represent the Congressional mandate under which NLM operates.

Today, the mission of NLM is a result of its own history, the central role it has had in medical research in the U.S., and the specific recognition by the Congress of the United States of its importance. As the legislative history shows, the National Library of Medicine Act (Public Law 84-941), passed in 1956 largely in response to recommendations of the Hoover Commission, authorized the Library to be responsible for a wide range of activities with respect to medical literature. Principal among them were:

1. acquire and preserve . . . library materials pertinent to medicine
2. organize (those) materials by appropriate cataloging, indexing, and bibliographic listing
3. publish and make available (those) catalogs, indexes, and bibliographies

These provide the specific context within which the panel was asked to identify objectives for the future of NLM. It has done so in challenging terms: With the promise in present and emerging technologies for information storage, accessing, transmission, and receiving, a reasonable ideal for a comprehensive health-sciences information system in the United States in the year 2005 would be a system in which any health-science professional could access databases from NLM and elsewhere easily and cheaply from any location with portable terminals so as to get immediate answers to vital questions and guides to further sources to meet non-immediate needs. While building such a system need not necessarily be, and probably could not be, the sole responsibility of NLM, NLM certainly can take leadership under its Congressional mandate toward stimulating the design and building of such a system in collaboration with publishers, technology providers, biomedical libraries, and health science institutions.

The NLM collection and its organization are the fundamental base on which such a system must be built. It is therefore essential that NLM maintain its responsibility as the "library of record" for the literature of

biomedicine. This responsibility is inherent in the Congressional mandate; it is central to the national system of biomedical information; and it is the basis for planning by all libraries, of every kind, throughout the country.

But the NLM, in its own planning for the future, must define its role in recognition of the new information infrastructure feasible in this electronic environment. Powerful communications technologies and international networks now permit the development of a coordinated, distributed library system that comprises the set of research collections throughout the country, each of them assuming archival and service responsibilities for selected portions of the literature. Such a distributed system represents a realistic response to the publication explosion and spreads the operational responsibility among a spectrum of institutions. In that way, for users located throughout the nation, distributed collections provide service enhancements not possible in a centralized system. The role of NLM then becomes twofold in such a system — both as coordinator and as library of last resort.

The new technologies permit and indeed require such a new information infrastructure, with compatible hardware, software, and network gateways on an international scale. Only in this way can the linkages be made to both traditional materials and new electronic ones to meet the needs of the medical community. In conceptualizing the expanded role of the NLM, information should be viewed as a function as well as a set of formats, and service should be designed to respond to users equipped with powerful capabilities for computing and communicating. Ready access to vital information resources and services, regardless of format or location, should become the object of the NLM.

Perhaps the most fundamental changes are occurring in the patterns of distribution of information. In the 17th century, the scholarly journal came into being as a result of a then new technology — the printing press. The journal article replaced personal correspondence by general distribution and thus served the same function as the town crier in announcing recent scientific facts. Today, in many fields we are supplementing the journal article with electronic memoranda, stored online for ready access. Tomorrow, these means for online communication may become the equivalent of the journal article as means to document information that is in regular use by scientists.

Indeed, in an increasing number of circumstances, information no longer appears in standard formats — i.e., as text in books, journals, or reports in either printed or electronic form — but instead is available as computer-based raw text, numerical, and even graphical files. The Census Report, the Chemical Information System of the Environmental Protection Agency, the National Health and Nutrition Surveys, epi-

demology data, and the gene splicing bank at the National Institutes of Health are available as computer data bases.

In the future, new technologies for optical and magnetic storage and quick retrieval of huge amounts of text at low cost will almost certainly generate new types of publications. While currently there are very few electronic journals and fewer that are not counterparts of the printed forms, this situation is rapidly changing and the expectations are that numerous journals may be made available online and as CD-ROM (Compact Disk-Read Only Memory) publications. The latter technology — optical storage in CD-ROM format — is in my view an exceptionally important one. Already we see publications ranging from the entire literature of the classics to law to engineering data to the literature of medicine being distributed in this form. And, as has been the case with so many of the information technologies, the library community has been among the first to demonstrate its utility. In fact, over half of the data files currently being published in CD-ROM format are bibliographic and reference files, used by libraries for cataloging and reference services.

Decisions concerning the collection and its organization surely must be made in recognition of the needs of the persons, groups and institutions it serves. Some are served by utilization of the collection at the Library itself; some by availability of that collection through interlibrary lending of documents and photocopies through the Regional Medical Library network and *DOCLINE*; some by the bibliographic tools, such as *Index Medicus*, that provide the means for access to the world's biomedical literature; some by MEDLARS and other NLM databases for use in online access service; and some by online access to databases produced by NLM, through MEDLINE and parallel access services such as TOXLINE.

The users of these services and their purposes vary widely from service to service, so generalization is difficult. It is clear from statistical data, though, that the principal user group is that composed of health care practitioners, with commercial users, biomedical researchers, educators and students having much lower frequency of use.

Among the groups served is the international biomedical community. The nature of research and scholarship as well as the global extent of disease have made service to it important to NLM. Of course, there is an international scope to the material that NLM must collect, so it is essential that NLM's collection policies cover the entire world's literature. The United States is increasingly dependent on the results of foreign research, so that we need data from other countries. The world of biomedical information is not limited to that produced in the U.S.; it spans the globe. The NLM collection must be international in scope to ensure document access.

But beyond the necessity to collect and to organize information internationally, the National Library of Medicine is uniquely important as the recognized world leader in biomedical communications. NLM's international stature is not accidental, of course, since it derives from its collection, the tools it provides for organization and access to it, and from NLM's positive, cooperative and substantive international programs: exchange of materials and services, MEDLARS quid pro quo agreements, the Special Foreign Currency Program, provision of policy and technical consultation on the development of national and international biomedical and health information resources, training of individuals who will subsequently serve as leaders or technical information experts in their countries, and joint programs with the Pan American Health Organization and the World Health Organization which have improved access to biomedical and health information.

NLM's policy, both nationally and internationally, has been based on a principle of sharing talent and resources rather than unilateral expenditure of funds. It has encouraged stable programs and operations and has enriched U.S. and international biomedical research and health. NLM has increased and improved biomedical communications in collaboration with scientifically sophisticated countries. Simultaneously, it has implemented activities responding to the needs of the developing world. These programs have enhanced human dignity, contributed to improved understanding among nations, and provided evidence of the national commitment to solving international problems.

It is especially important to note, in both the international arena and the U.S. itself, that there are great differences in the ability to deal with new technologies. Small, developing countries and small communities in the U.S. may lack the resources for them. Therefore, for at least the coming five-year period, and possibly even for the twenty-year period, it will be essential for NLM to continue to provide its publications and services in the traditional forms as well as in the newer forms.

The Future of the Collection

There was wide-ranging discussion in Panel 1 concerning the media to be acquired. Would print and paper media still be important? Should newer media, such as CD-ROM, be actively acquired? What about numerical databases, patient record systems and data, expert systems and other artificial intelligence packages, software more generally?

The Collection Development Manual of the National Library of Medicine 1985, is a comprehensive document which not only provides pertinent historical background regarding NLM's collection but also delineates its scope and format and provides guidelines for the selection

of non-traditional formats. The views of the panel appear to be consistent with those guidelines, but they may provide some additional perspective on them.

Even with radical changes in communication patterns in some fields of science, including areas of biomedicine, as will be discussed below, Panel 1 strongly believes that print and paper media in the traditional formats of books, journals, and reports will continue to be important forms of publication and acquisition for the NLM collection over the twenty-year frame of reference. There are a variety of reasons for this belief: First, these media will continue to be an economic form of publication. Second, users still demand hard (i.e., paper) copy, and there will always be groups that will need their information resources in traditional forms. Third, when new information media appear they do not replace the older ones, even when the predictions have been that they would do so (the example of "media" and microforms of some twenty to thirty years ago provide evident illustrations). Fourth, many users, such as those in small hospitals and in developing countries, will not for many years have the equipment and resources needed for use of newer media.

There is a wide range of electronic forms of publication either already in being or soon to be so. With respect to all of these kinds of materials, it is important to the health care community and to the nation's health sciences libraries that the NLM continue in its leadership role, to make sure that the informational records of biomedicine, whatever the format, may be preserved and made available for present and future scholarship. These newer formats represent the technological experiments in packaging information. While we may not know what the ultimate package is going to be, it is crucial that NLM, in cooperation with other agencies, define the ways to impose "bibliographic control" on the new formats and, most important, to find ways of guaranteeing "integrity of reference" — the audit trail which identifies where information was obtained and permits the reconstruction of exactly what that information was at the time it was obtained.

New technologies for optical and magnetic storage and quick retrieval of huge amounts of text at low cost will almost certainly generate new types of "publications." Unless the NLM oversees decisions and influences standards it will have to apply in covering these new publications within its overall mission and scope, they are highly likely to generate problems post hoc for the Library.

What kinds and parts of electronically published literature should NLM acquire? In what medium and format should be NLM expect publishers to deliver such publications, both for indexing and storage? Should the NLM define such needs as including printed-out versions of such materials? Probably most important of all, what should the policy

of the Library be with respect to remote accessing of such materials, and how would its policy relate to copyright issues? Defining the problems to be dealt with, in collaboration with publishers and technical experts, should have the highest priority for NLM. The NLM should take the lead in setting standards so that its needs will be met. It must carry out its own mandates and help to guarantee the integrity of the health-science literature for the user community at large.

The consensus of the panel with respect to the scope of the collection was that the collection policies should apply to electronic media as they do to printed. In particular, it is crucial that the focus be on "unpublished" data, that is, data that is distributed and publicly available. Electronic storage raises extremely difficult issues related to intellectual property rights; agreements must be reached with publishers of the full spectrum of materials to provide the basis for accessibility and use while recognizing the property rights. When access rights with no machine readable copy of an electronic publication are ordinarily granted to a subscriber, the National Library of Medicine, prior to subscribing, must negotiate with the publisher to assure that the publications will be preserved by the publisher or that the Library will be granted the right to download the publication for storage in its own collection.

With respect to these new media, Panel 1 was especially concerned about the need to assure the future availability of data stored in dynamic, online files. As it is now, databases developed by other organizations are not collected by the NLM; access to them is provided only for on-site users, via telecommunications links with other computer systems. But data currently available online may no longer be so available in twenty years. In what form will those data be stored, and what responsibility does the NLM have to assure their future availability? Reference was made in panel discussions, to which I have referred above, to the concept of "integrity of reference," interpreted to mean that data to which reference is made today should be available in the future as the same data, unchanged; the problem is that in dynamic files the integrity of reference may be lost.

The vast historical collections now at the NLM, including a significant archive of manuscripts, constitute a national treasure. It is used by scholars from all over the world. The History of Medicine Division houses and maintains this collection and produces an annual bibliography of the history of medicine as well as useful catalogs of specific portions of the collection. Most recently, the NLM has provided an online database of references to the field used by scholars throughout the country.

Considering the value, both intrinsic and informational, of this historical record, the NLM should continue to acquire materials of

historical significance for its history of medicine collection in support of present and future scholarship. In the future, non-traditional formats should be considered logical candidates for acquisition.

Preservation of the Collection

The panel endorses the recently developed preservation policy of the NLM, as set forth in *Preservation of the Biomedical Literature*. This policy is in accordance with the terms of the National Library of Medicine Act and the clearly expressed intent of Congress. It confirms the fundamental responsibility of the NLM to preserve permanently the content of books, periodicals, and other library materials pertinent to medicine, based on the guideline described in the *Collection Development Manual of the National Library of Medicine*. With the view that NLM's principal responsibility is to ensure the preservation of the core biomedical literature, the panel urges that NLM give high priority to implementation of the preservation policies.

A manual is to be developed setting forth operational guidelines and procedures for selecting items to be preserved, choosing preservation techniques, and processing items for preservation. The basic policy document, *Preservation of the Biomedical Literature*, proposed a planning structure to the year 2000 with review every three years; the principles are readily extendible to the year 2006, the period of concern to this current planning process. It discusses the establishment of a new Preservation Section in the Public Services Division with responsibilities for the management of preservation programs, collection maintenance, technical preservation and conservation, education and public information, and consultation and research. The latter function would be coordinated with the Lister Hill Center and other organizations. Such research efforts are crucial in the coming years for all formats, including especially electronically stored data.

The optical disk, with the capacity for storing both audiovisual and digital information, will provide a storage medium with high-speed search and review capabilities and immense capacities. The videodisk and the CD-ROM (Compact Disk-Read Only Memory) will provide excellent formats for storage and access. The Lister Hill Center should continue research on the characteristics of these formats based on the prototype Electronic Document Storage and Retrieval (EDSR) system being developed there.

Various electronic media are going to be available for "permanent" versions of electronic publication: CD-ROM, magnetic disks, and so on. What will be the "shelf-life" of the various media? Which ones will be most economical as a method of access? What are their limitations with

regard to special displays — special characters, graphics, line or continuous-tone? The decisions made by the Library with regard to these matters will almost certainly have a heavy influence on what will be done elsewhere in the library world. The problems and possibilities should be defined as soon as possible; these are not problems that will emerge only after 2006.

There was a general consensus that NLM should take the lead in working with other agencies, both public and private, in resolving the technical issues involved in preservation of the electronic record. The NLM should take the lead in setting standards for its needs in carrying out its mandates and toward helping to guarantee the integrity of the health-sciences literature for the user community at large.

The issue of preservation of governmental data bases in particular requires special consideration in order to formulate a policy. While the NLM cannot assume the task of assuring the preservation of all governmental databases, it should attempt to assure that those related to biomedicine, even when not under its purview, are preserved. By cooperation with the National Agricultural Library and the Library of Congress, NLM should seek to establish agreements to preserve electronic media that are related to biomedicine and meet its criteria for preservation.

Major questions to be addressed include:

- 1) What information should be preserved? Data such as statistical compilations or bibliographic databases would seem to require storage which allows manipulation. Textual data such as administrative or program records are now often being transferred from paper to machine-readable form and raise such issues as storing this material on a medium for which the proper equipment or programs may not be available for use in later years. Another issue is that the storage of information chronologically on disks may eventually lead to unmanageable index sizes in order to provide access to the data.
- 2) For what period of time should information be preserved? Obviously the range is great — from one day or less to forever. Different kinds of information fall into different categories, and agencies must develop policies according to their information types.
- 3) How should information be preserved? For medium to long term or archival, magnetic tape and optical disk are the two preferred storage media at this time. The latter is progressing out of the research stage and emphasis is on mass production. Life expectancy is still uncertain.

In this area, the policies of the federal government are fragmented. NLM should participate in activities for policy development at the national level to address these problems.

While the preservation of NLM's own collection is a major step toward the preservation of the entire scholarly biomedical record, NLM also has a responsibility to assist the preservation of important biomedical literature held by other U.S. institutions. NLM's preservation efforts are to be coordinated with those of other national libraries, research libraries, and biomedical libraries.

Much of the preservation problem can be stopped at its source if the scholarly record is published on archival media that are not predisposed to rapid deterioration. To lessen the need for preservation treatment of future publications, NLM shall actively encourage the publishing industry to use more durable materials in the production of the biomedical literature.

Organization of the Collection

In the discussions of Panel 1, "organization of the collection" was interpreted as including all aspects of technical processing, cataloging and access to catalog records, indexing and the production of *Index Medicus*, research and the development of new methods in each of these areas, and the variety of cooperative efforts such as the development of standards for them.

While perhaps self-evident, the panel felt it was important to emphasize the absolute necessity that NLM continue to publish *Index Medicus* and to maintain the MEDLARS databases and other indexes to key biomedical research and clinical reports. These tools are central to the organization not only of the collection of the NLM itself but to the operation of every medical library throughout the world. In fact, because of its international importance, it is valuable for NLM to continue to use cooperative arrangements with foreign countries to provide for access to international publications.

During the past two decades, the frontiers of medical science have undergone remarkable change. On the one hand, they have extended deeply and more widely into the basic sciences; on the other, they have become increasingly concerned with integrative mechanisms and communication at all levels of organization. Moreover, as fundamental levels of science are drawn upon, distinctions between basic sciences have become increasingly blurred.

The data bank of the NLM is comprehensive in its coverage of clinical medicine and the "traditional" basic sciences but less complete in new arenas, e.g., biochemistry, bioengineering, molecular biology, and genetics. Three solutions seem reasonable for this inevitable problem of keeping pace with changing directions and frontiers in medical science: 1) enlarge

the scope of the data bank, 2) establish links with other data banks to complete the picture, or 3) a combination of the two.

If resources were unlimited, the scope of the NLM data bank could be broadened to include the new interests and horizons. More likely are the boundary conditions of constrained growth in resources so that some trimming of the current data bank will be required. Therefore, NLM should work with other producers of indexing publications and databases in evaluating the means to share common data while maintaining the value of subject-specific indexing. This may require research evaluating the scope of materials appropriate to such sharing, the degree to which specificity in indexing is necessary, the means for sharing data and supplementing it to meet the needs of the individual publisher.

As a reasonable first step, the NLM could take the lead to make other databases available to its users and to establish links with banks of needed materials that fall beyond its purview. At present, individual data banks collect data in their own styles and do not provide data in identical or similar ways; this discordance complicates the search and renders it more costly. As a first step, NLM should, in cooperation with other organizations, develop links between MeSH (Medical Subject Headings) and other vocabularies. Such arrangements with relevant indexing and abstracting agencies could lead to the development of the cross-linkages that would make it feasible for NLM truly to become a switching center for access to all relevant literature.

Another aspect of this problem is defining the boundaries that will be encompassed in the NLM data bank itself. At first encounter, the blurred boundaries between medicine, basic science and related science may appear difficult to sort out into manageable form. But, with the aid of professional societies in the basic sciences, citation indices, bibliographies in journals devoted to clinical research, and scientists — both clinical and basic — limits could be defined for contemporary and foreseeable future needs in science.

A good deal of the discussion therefore was concerned with coverage in the MEDLARS database. Currently, though there are criteria for selection of journals for inclusion in MEDLARS and its various component databases, in general they have been selected for indexing by largely informal methods: ad hoc judgments, opinions of consultants, recommendations by subject and geographical experts. The extent of the overlap of MEDLARS with other database systems such as BIOSIS has also not been determined by formal criteria but by the results of the MEDLARS selection process. Application of bibliometric methods, including citation analysis, should be tried by NLM both for selection of serials and for periodic assessment of current scope. Such formal methods might help to insure bias-free selection, adequate representation

of currently important and new subject areas, and appropriate classification or stratification of serials for particular search needs.

The question of NLM policy with respect to inclusion of electronic journals in the indexing process was considered by the panel. Although there are not yet any procedures for handling that question, in principle NLM should consider a policy based on the requirement that, to be included in indexing, the material must be available in archival form in order to assure continued future availability and guarantee integrity of access. The requirements with respect to acquisition apply with equal force to the indexing of such materials: they should be covered by *Index Medicus* only if they are publicly available.

The panel applauded NLM's past efforts to establish tools for cataloging materials in its collection that now represent the internationally accepted standards — Medical Subject Headings (MeSH) and the National Library of Medicine Classification Scheme. It is essential for the operations both of NLM itself and of the biomedical library community of the country and even of the world that NLM continue to maintain these tools as the basis for subject access and logical organization of materials. They provide the rationale for the structure of the NLM catalog and the means for access to the collection; they are essential tools in technical processing; and they provide authoritative data for use by other health sciences libraries.

NLM should continue to cooperate with other research libraries in the development of standards for bibliographic description. That would include, in particular, continued participation in national programs such as CONSER, CIP, NACO, and the Linked Systems Project. These efforts are intended to make descriptive cataloging data compatible among the major cataloging agencies so as to ensure easy exchange of data, provide users with standard points of access regardless of the source of the data, and reduce duplication of effort through sharing of data. Of special importance is the effort in NACO to build a consistent name authority file which will link together works by the same authoring body regardless of form of name.

Regardless of the form of material, whether hard copy, microform, or machine-readable form, and regardless of whether one is providing access to a citation that represents an item on shelf, or providing access to the content of an item in electronic form, that material must be placed under bibliographic control. Bibliographic control is the function that provides access by author, by title, by subject, or other criteria to the document itself or information in it.

NLM should provide leadership in the investigation of additions to the cataloging records that will provide more detailed descriptions of content. Data derived from the text, such as tables of content, legends

from illustrations and tables, and similar structural elements can serve as the basis for selection and for assuring greater specificity in the portions of materials that are requested and presented.

In cooperation with other research libraries and national libraries, NLM should participate in the development of formal tools to support cataloging decisions. These may take the form of "expert systems," embodying heuristics for good practice and draw on databases, authorities, and algorithmic rules, but they will provide the means to assure greater uniformity in cataloging and more effective interchange of data.

Expert systems will not replace bibliographic control, but should be investigated as a possible technique to assist in cataloging, the function which provides bibliographic control. To reduce costs, the national libraries have already begun to explore the applicability of expert systems to the cataloging function, and this should continue into the future.

The NLM is supporting planning and research efforts to integrate access to disparate databases containing clinical patient data, biomedical research findings, references and text from published literature. Providing unified access to this variety of databases requires development of means for mapping the vocabularies used in them. To this end, NLM has established creation of a Unified Medical Language System as a priority program.

The Unified Medical Language System would include dictionaries and thesauri, cross indexes among them, automated tools for indexing and classification, computer programs to process records and evaluate their conformance with standards, and programs for updating and maintaining these files. The plan is to include cooperative efforts with NIH, the American Medical Association and other professional societies, university investigators, and other agencies.

The panel heartily endorses this development. NLM should vigorously pursue the development of the concept of a Unified Medical Language System and, as appropriate, apply the results of that research to the cataloging and indexing activities of the Library. The panel's discussion identified several values: linking patient data with scientific data, increasing the ability of practitioners to use the literature, improving the efficiency of searching, facilitating application of computer methods in medicine, and linking different kinds of information sources.

Conclusion

The report of Panel 1 concluded with a set of recommendations, presented in two categories: general recommendations and "windows of opportunity." The former were regarded as long-term, to guide the NLM

in future policy decisions; the latter, as contexts for immediate action because the opportunity to accomplish them effectively may vanish within a short time.

I will not here review the full array of recommendations, since they are largely implied by what I have already said. But I do want to conclude by emphasizing the recommendations that are to me especially important.

First, NLM must continue to be the "library of record" for biomedicine. While that must be interpreted in realistic terms, the principle should govern decisions. Second, NLM should set collection policies that cover acquisition of materials in the full range of media. While the newer media will become increasingly important, it will be as additions to print, not as replacements for it. Third, NLM should work closely with publishers to assure that the means for bibliographic control apply to newer media at least as well as they do to printed forms. Of special significance is that means be developed to assure maintenance of "integrity of reference" as computer-based forms result in dynamic change of files. Fourth, NLM must continue to publish *Index Medicus* and to maintain and provide access to the MEDLARS data files. These are central tools for all libraries and must continue to be available from NLM. Finally, NLM should continue in its role as the international resource for biomedicine. This is a world-wide responsibility that is completely consistent with national objectives and self-interest.

Nancy M. Lorenzi

Henry Wendth, President and Chief Executive of Smith, Kline, Beckman Corporation states, "It is essential for corporations to operate as fully integrated organizations, in which each of the parts supports some vital role of the other parts, or in short, we must look at the corporation as organic, not mechanical."⁽¹⁾

The corporation of the future must be, to use the words of MCI Chairman and CEO William McGowan, "lean, mean, and linked up." There will be stronger channels of communication and decision making.⁽¹⁾

Introduction

Whether it is John Naisbitt in *Megatrends*, or many others in academic publications, everyone says that we are in the "information age." There are many statements about the United States as an information-based society, about our abundance of knowledge workers, our systems, and so forth. Statements about the information age appear in such diverse sources as the comic strips, *Business Week*, television, radio, subway posters, and backs of buses.

While all of the words are "true," it is my belief that we may understand the "information age" concepts at the intellectual level, but we do not understand the concepts at the "gut" level. The basic premise of this paper is that American organizations whether they are Fortune 500 companies, hospitals, or academic medical centers, have not changed their basic organizational structures in this "information age." The two goals of this paper are:

1. To stress why organizations need to create an organizational philosophy and possibly an organizational component whose focus is to *integrate* the "information age" concepts, namely, massive amounts of diverse information (content), linked to the organization's members (users), whether directly or indirectly, through invisible or nearly invisible means (infrastructure), with technology forming a basic foundation for the system. Thus the organization's goal is to be user/content-driven.
2. To stress the National Library of Medicine's integrated information role regarding health sciences information for the United States and beyond.

In order to illustrate why an integrated information philosophy is such a complex organizational issue, this paper stresses the following: the historical perspective, current organizational needs for creating an in-

egrated information organization, the complex issues which abound in today's organization, proposed benefits for creating an integrated information organization, a view of "an integrated information organization," and strategies for achieving an integrated information system. In addition, specific attention is paid to the National Library of Medicine and, in particular, NLM's strategic planning process with the focus on the *infrastructure* and *users* as presented by Panel 2. Finally, a year 2005 challenge is issued for the National Library of Medicine and for all persons responsible for future planning and organizational direction.

Historical Perspective

As we look at American organizations, we see that when information as an organizational issue is considered, technology is treated as king or queen of the domain. In other words, organizational decisions regarding information have traditionally been technologically driven. Many of the chief executive officers, not wishing to acknowledge their lack of understanding of information or computer technologies, abdicated the organizational issues and considerations of the "information age" to the technical people. As Paul Strassman states, "the usual approach to dealing with the effects of information technology is to first examine its supply side, which includes the technology of computers, software, communications, information services, applications, databases, printers, memory devices and so forth."⁽¹⁾ For the last 25 years, we have been preoccupied with the supply side issues.

In describing our approach to office automation, Strassman goes on to explain that "over 95 of every 100 pages of text written about office automation have dealt with [supply side] aspects." He further explains that concentrating on the supply side was necessary at the beginning stage of technological capabilities, since the audience was primarily the more than 2,000,000 technologists involved with the design, manufacture, and application of the programs. When the trend to personal computers began expanding, the same philosophy about information (i.e., being technically based for technicians) was still the predominant form of communications, even though the actual users of computers could absorb only small doses of useful knowledge about computers from this literature.

This supply side trend was expressed organizationally by creating centralized computer centers which were often organizationally isolated from the technology's ultimate user. And, equally as important, such centers did not necessarily have a direct organizational connection to the decision support systems of the parent organization.

Current Needs

All indications point to the need to push for internal organizations capable of developing the concept of integrated information as a system within today's organization. By integrated, I mean the linking of available and necessary information to a specific user at a specific time and in a format that the user desires. Thus, from a terminal in a patient care area, the physician should have access to the patient record, X-ray data, laboratory data, including the pictures of the X-rays and the pictures of laboratory specimens, library information, billing information, educational support information, knowledge base information, help with decision making and many more products and services.

First, there is a definite *demand* for integrated information to better assist with decision support, competition, quality and other related concerns of the contemporary organization. Eliyahu Goldratt, in his book *The Goal*, states that "... in the executive suite at company headquarters, they've got measurements like net profit and return on investment and cash flow, which they apply to the overall organization to check on progress towards the goal." But, he continues "... at the plant level, those measurements don't mean very much... I don't think they're really telling me the whole story."² Thus we find ourselves in organizations with large amounts of raw data, but lack of information to tell the "true picture" of what is happening in our plants, in our hospitals, and in our medical centers.

Second, *stress* is high in organizational systems. Without an integrated information philosophy, the stresses continue and the frustrations with inadequate information upon which to make basic decisions mount. We cannot make effective long-term decisions about production, patient care, service, education, or communication without effective and complete information to support the appropriate decision.

Third, the *content* of information keeps exploding. The greater the explosion, the more data, the more frustrated we are with how to handle this data and determine its meaning. We cannot effectively move forward if we have no systematic way of linking our information needs with successful organizational strategies.

Fourth, we have *technology*. There are mainframe computers, minicomputers, microcomputers and various combinations thereof. We are now using fourth generation technology. Soon we will be using fifth generation technology, which will attempt to replicate our thinking processes and might, conceivably, effectively sort out decisions and systems. Edward A. Feigenbaum and Pamela McCorduck state that the Japanese are currently planning a miracle product: "The miracle product is knowledge, and the Japanese are planning to package and sell it the way

other nations package and sell energy, food, or manufactured goods. They are going to give the world the next generation, fifth-generation of computers, and those machines are going to be intelligent."⁽³⁾

Finally, the *people* in today's organizations are increasingly more sophisticated about their information needs and the technology to obtain their needs. The users, coupled with the demands for packaging the content and the technology together, form the impetus for an organization to accept the challenge and develop an integrated information philosophy.

Complex Organizational Issues

If organizations truly have the needs I have outlined, why have we not reorganized to answer the needs?

Traditionally, organizations organized themselves by very specific content areas, e.g. finance, personnel, libraries, computers, manufacturing, etc. Once an organizational structure is in place, it becomes very difficult for one unit (such as a library or a computer center) to become subservient to any other unit. In addition to the enormous political processes which occur to ensure that one does not become organizationally subservient to another, there is a general reluctance in any organization when it comes to the possibility of massive restructuring. Many organizations fear an additional financial burden will be created for a "new" or "restructured" unit. Since several of these factors compound each other, organizations do not readily undertake *any* major restructuring. Thus, creating an integrated organization for information must overcome these obstacles and many more.

Most American profit and not-for-profit companies are very complex organizations which have not taken the time to develop a conceptual model of what integrated information means for their system. Most organizations try to "patch" a new entity into the current organizational structure. Thus, the "easy" option is to view the organization in the same way that we have for generations rather than plan and possibly reconceptualize the organization. The reconceptualization requires a high commitment of energy and resources, not to mention keen political skill.

Organizations are very political animals and everyone has a vested interest in a particular viewpoint or department. An organization today may fight too many internal political battles and individuals may pay too much attention to self-serving behavior rather than examining total organizational behavior. Finally, financial issues are, as always, important to consider here. Organizations need to protect their "bottom line" and thus the time, political intrigue and money necessary to engage in

complex organizational change may not seem to be warranted from a financial point of view.

Benefits to the Organization

Adopting an integrated information philosophy allows an organization to be effective, interactive, flexible, supportive, evolutionary and open to change. The organizations that accept this integrated information philosophy can function on the demand rather than supply side of the curve. The demand side is driven by the *users* and the *content* that they need. Thus, the business of the organization, whether an academic center, or a hospital becomes paramount in the process. The integration of information philosophy allows a linking of the users and the content through nearly invisible technologies. The integrated information philosophy allows better planning with regard to "where are we going in the future," "what types of changes and directions do we need to make," and enables the organization to be responsive to changes on the horizon or in the long term future.

The new integrated information unit can not only integrate the information (content) for the users, it can also assist with strategic planning, strategic positioning of the total organization. The integrated information unit can assist, as well, with the creation of standards and the basic infrastructure for the delivery of information.

If an organization is to adopt an integrated information philosophy, it needs *standards* of how the various departments will provide data and under what circumstances and contexts individuals and units will have access to information. In a well-planned organization, a single department cannot independently outline the standards for the entire system; it takes a total systems point of view to provide system standards.

Finally, the infrastructure provided by an organization is the invisible "highway" or "network" on which information travels from the source to the requestor. The infrastructure is never completely technological. It also includes a staff who know about people, who have knowledge about certain topics or content areas, and who can efficiently direct users to those experts. The "people connection" infrastructure happens in medicine all the time. We need to continue the feeling of the people to people connection. Many studies have demonstrated that physicians receive much of their information through verbal means from colleagues. What are appropriate substitutes for those colleagues that might have more up-to-date information and that might be packaged in such a way that it is more easily obtainable to the physician or to any one of the people supporting that physician and his/her patient?

The New Integrated Information Organization

We cannot predict from organization to organization what an effective integrated information organization will look like. A basic underlying philosophy must be that the integrated information organization needs to have a conceptual and an attitudinal integration. The integrated information philosophy has great implications for a unified organization, but a unified organization will not guarantee organizational integration. To explain further, there must be an attitude within the organization which stresses need, philosophy, users, context, process, and the future if the conceptual framework to integrate is to be effective. In many organizations this has implications to create a new unified organization, with one person in charge. A dominant factor for the creation of such an organization under one person revolves around the attitude, leadership, and the competence of the one individual to ensure that the new organization will be created.

On the other hand, if the top leader demands that the total organization be integrated, then it is possible for an organization to create an integrated information concept and philosophy with various components of the organization reporting to different people. This system, with the commitment of the top leadership, may need minor modification for it to become the totally integrated information system.

In the typical organization, some action steps might be as follows:

- Create a task force to study the needs of the organization to become engaged in or to pursue the concept of integrated information.
- Establish a direction for change, including timing, what will change, and stages. Once the directional plan for change is agreed to, then the implementation process can be legitimized by the organization and thus the integration will not be as difficult as in the organization where the need for the integration is seen from a bottom-up rather than a top-down perspective.
- Presidential and top leadership approval is required in order for the new organization to have total system legitimacy. If the president or chief executive officer decides that this is the way the organization will be, then it is very difficult for the obstructionists in organizations to obstruct.
- Create a strategic plan. The strategic plan outlines the visions for the future, what should be accomplished, what could be accomplished, the dreams, and what individuals and units should be capable of achieving.
- Select an appropriate leader. The leadership selection for this new entity becomes crucial. Leadership selection could be made before

the strategic plan is developed so that the new leader is charged with the responsibility for implementing the strategic plan or after the strategic plan if the organization wants to select a high calibre person who matches the philosophy and direction of the parent company.

The National Library of Medicine

The National Library of Medicine has a long tradition of outstanding achievements. From the original goal of collecting medical books, to the organizing of medical information, to the creating of new information or new ways to display that information, the National Library of Medicine has been the world's leader.

If we consider the U.S. government as the Fortune 1 company, then this Fortune 1 company has the largest income, expenses, employees, products; it is highly diversified and its stocks haven't been selling very well recently — mostly on the penny stock market — but there is a lot of value added and emotion that make its stocks worth a tremendous amount of money. This Fortune 1 company has more than 241 million customers as its direct "shareholders," and uncounted millions as indirect "shareholders." One organization in this Fortune 1 company is the division that supplies medical information. This division, the National Library of Medicine, is also charged with the integration of information for the health care of this Fortune 1 company. The National Library of Medicine has only .005 percent of the total budget of the Fortune 1 company and .02 percent of the entire staff of the Fortune 1 company. Ultimately, the results and efforts of this one division will affect the quality of life of all 241 million shareholders. It is thus imperative that the integration of information role of the National Library of Medicine continue to be acknowledged and supported as we move into the next 50 years of the National Library of Medicine's existence.

In 1985, the National Library of Medicine began a strategic planning process consisting of five conceptual panels. Panel 2, "Locating and Gaining Access to Medical and Scientific Information," concentrated on the users and the infrastructure. Panel 2 viewed the long-term vision for the National Library of Medicine as the *official organization* within the Federal government to be responsible for facilitating, planning, creating, and developing the standards for bibliographic areas, content and systems, nomenclature and so forth. Panel 2 sees the National Library of Medicine as responsible for continuing to update the infrastructure for the delivery of the needed information. The infrastructure will be both on the supply side, that is, the technological aspects from the computer to telecommunications, and the demand aspects, from the information

requestor, linked with the information source which may employ intermediate nodes, as necessary, to expedite the information transfer process. The National Library of Medicine should be charged with developing nationwide efforts for how information should be integrated in order to better support the bottom line philosophy of the parent organization.

The National Library of Medicine should be charged with developing nationwide efforts for how information should be integrated in order to better support the bottom line philosophy of the parent organization.

At the beginning of this talk, I promised a challenge. A challenge for the year 2005. All of the strategic panel reports for the National Library of Medicine are aimed toward the year 2005. Last October, I had the opportunity to speak at the Fifth International Congress of Medical Libraries in Tokyo. I issued a challenge at that Congress. It is the same challenge that I issue today. The difference is, for many people in the Tokyo meeting, the challenge was a distant vision, but the challenge for those assembled in this room today can be a reality by the year 2005. The challenge is to create *WORLD NET* (World Over Resource Library Directory Network).

WORLD NET provides access to literature from all parts of the world. The literature is instantaneously translated by computer into the native language of the user requesting the information and is accompanied by visual images. *WORLD NET* provides access to knowledge bases created by the experts, regardless of their geographic location, and also provides access to the experts who are available to assist with questions surrounding the problems of health care. Translation is instantaneous and thus, if necessary, an expert from one location in the world can communicate immediately with a physician or a patient from a distant land in another language. *WORLD NET* provides information so that experts across the world can build in a synergistic fashion.⁽⁴⁾

The two-fold theme of this paper has been the integration of information as an organizational entity within a given organization and NLM's role in the integration of information for a total system. A basic Level I for the integration of information is the creation of standards. This not only requires each library to have a standardized organization of its materials, but it requires international cooperation for this standardization of materials. And who best in the entire world to fulfill that role but our National Library of Medicine. The National Library of Medicine's worldwide integration of information organizational role continues to expand in Level II. Abraham Maslow's terms of hierarchy of needs include policies and practices. These policies and practices form the independent, but potentially interlocking nodes of the major *WORLD NET* health information system. Technology which was impor-

tant in Level I becomes more important at this time. It is essential that a technological infrastructure be in place in order to make possible the accessibility at the local, regional and national level. Research is essential also at this level to begin small prototypes or models which would demonstrate the complete integration of information networks and which would provide a taxonomy of locations, areas, content and so forth.

Level III is a broader geographic expansion of the Level II research, models and prototypes. Once the resources are organized and the appropriate technology and people are in place, the beginning of integrating the different informational systems becomes important. Research continues at this phase in order to handle the international taxonomy of language and linguistics. All this leads to Level IV — WORLD NET.

The year 2005 challenge for creating an integrated information organization in our respective organizations and for the world is overwhelming, but it is the effective integration of information which makes possible the vision of WORLD NET. The Panel 2 members support the integration of information and the National Library of Medicine's past and future roles to make this vision a reality.

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Research Frontiers in Factual Databases: Molecules and Megahertz

Daniel R. Masys

The Long Range Planning Panel whose subject domain was "Obtaining Factual Information from Databases" foresaw a future which calls to mind a cartoon that Pogo author Walt Kelley might have drawn, but didn't: Porky Pine asks "If we gonna make smart machines, don't we gotta make us smart first?" Pogo offers his classic response: "Yep son, we have met the enemy and they is us!" This is more true than it might seem at first glance: we are already entering an era when the technology to store, manipulate, and transmit our most complicated ideas can accommodate most any form and function that we can conceive. The rate-limiting step is becoming our own imagination, and our understanding of human cognition; this generalized symbol processor, the digital computer, will be our able servant if we can but think ideas on a perceptive enough scale to solve the problems we wish to solve.

To examine the frontiers of factual databases, we need first to define the subject. Factual databases consist of knowledge, information, data and signals that have been represented in electronic form, generally with a structure that allows the content to be selectively retrieved and communicated via processes which are also electronic. Within this definition fall those collections of data which might narrowly be termed "factual," for example, a listing of the molecular weights and physical characteristics of a group of chemical compounds. However, it also includes collections of visual images, sounds, electrical signals, and even editorial input, such as the opinions of human experts about a particular issue in biology or medicine. In fact, it is a domain so broad that a synonym might be all "non-bibliographic" databases. Unlike bibliographic databases, which point to information located elsewhere, factual databases contain the information sought. As such, when a factual database is composed of documents containing the observations and opinions of human authors, it is in essence electronic publishing, differing from print publications only in its mode of access.

For purposes of the National Library of Medicine, factual databases fall into three areas: those that exist to protect the public health and environment; those that are designed to support health care delivery, which we call practice-oriented databases; and those which are designed to assist in the conduct of biomedical research.

What will the world of biomedical knowledge resources look like twenty years hence? It is not difficult to image an information-rich environment populated by professionals in the field of biomedicine who use machines as intelligent assistants for most of their work. Interacting easily, either by spoken natural language, or by use of graphical pointing devices attached to electronic displays which are as finely detailed and easy to read as today's magazines and newspapers, the user has access, quite simply, to all that has been recorded about a subject area of interest. This involves intelligent retrieval interfaces, which transform the human's request into an appropriate retrieval syntax for another computer, and transparent gateways, by which related information from many different databases residing in local and distant databanks can be gathered based on a single request by the user. All of this occurs for a price, which is known and perhaps even negotiated beforehand by the requestor, having been estimated by his own machine's retrieval program. For most information, especially that gathered and validated by government health agencies, we expect that the cost will be reasonable and not an impediment to the successful performance of one's professional tasks; for some privately held information, it will be, as it is today, whatever the market will bear.

Factual databases for the public health and environment will include the collected experience of dealing with the hazards and pollutants of our industrial society, accessible instantly by those who must respond to the inevitable mishaps such as toxic chemical spills. Using portable computers whose programs model a human expert's reasoning about a hazardous material, on-site emergency teams will engage in a dialog with their electronic assistant just as they now do with human experts, and the machine will automatically connect via phone lines or radio to gather related information from perhaps hundreds of different factual databases located around the country, even around the world, to synthesize recommendations regarding immediate management of the calamity, evacuation of surrounding areas, follow-up. These recommendations may be spoken to the user via machine-synthesized voice, since most emergency sites are not well suited for thoughtful reading and contemplation.

In the area of public health and policy, hospital administrators and peer review groups will easily be able to ask questions of risks, costs, and benefits regarding new and established therapies and technologies, and have the data gathered automatically from files maintained in scattered geographical locations. Much of this data will include machine-analyzable data files, to which a hospital or clinic's local experience can be compared and graphically displayed.

In the practice of medicine, the doctor and allied health professional will have access to a collection of online textbooks which are always up-

to-date, being maintained by editorial boards of medical experts. If a doctor's personal clinical experience varies from the outcomes referenced by experts, he will have an electronic communications link, to comment upon the textbook or post a question on an electronic bulletin board used by other health professionals. Practice assistance will come both from factual databases intended to be communicated directly to users, and those factual databases which contain the encoded knowledge of disease, diagnosis, and therapy which are integral to expert systems. These expert systems will accept descriptions of clinical problems, and analyze them using both prestored facts and sets of rules by which, given certain facts, a conclusion can be reached.

The biomedical researcher will similarly have an intelligent assistant, a machine that allows him to simply request technical information or, at a higher level, to postulate a theory in natural language. His intelligent interface will search for related facts which uphold or refute his hypothesis, assembling them with suggestions as to possible links (to the extent that it is able); again the query will be cast via computerized gateways to a large number of different databases, each maintained by its own group of subject experts. With data gathered from his own experiments, from distant sources, or both, the researcher will easily be able to create computerized models of the biologic system he is interested in, and graphically portray the effects of manipulating that system.

It is quite easy to paint such utopian scenarios, but what evidence is there that these things will come to pass? Looking at examples of what exists today should point to how far we have to go.

In the area of public health and environmental factual databases, the Library has since 1972 had a number of factual databases containing information about the toxic effects of hazardous chemicals.¹ Today, the best example is the Hazardous Substances Data Bank (HSDB®), which contains very detailed records of over 4000 of the most environmentally important toxic chemicals. The information in the database is reviewed by a panel of experts to maintain accuracy. To use effectively such a database today, one needs to know a command language, both to locate the records of interest and to limit the information found (since HSDB is divided into over 200 different subcategories for each compound). The greatest need in such cases is for intelligent and friendly programs that function like a good reference librarian to converse with the user about what information is needed, then make automated information source selections, and carefully directed automated retrievals.

In the area of health-care practice-oriented databases, the first examples of online textbooks and treatment decision support have appeared. The National Cancer Institute's PDQ database allows use of numbered menus for inexperienced or occasional searchers, as well as command-

driven searching for those who do not need menus.² PDQ covers the area of cancer, but it currently stands alone as a comprehensive national factual database for a specialty area of clinical medicine. The coming years will need to see development of a critical mass of such computer-based decision aids in all disease areas, and the remodeling of physician information-gathering habits to include use of computer-based tools.

In the area of biomedical research, the science which holds the highest promise of discovery in the coming decade includes the disciplines of molecular and cell biology. We are now able, with automated laboratory techniques, to analyze complex molecules composed of thousands of smaller subunits and millions of atoms. Our task is formidable: the human genome, for example, is composed of 3 billion base pairs of DNA that make up between 10,000 and 100,000 individual genes. Using recombinant DNA techniques, so-called genetic engineering, we are gaining the power to change the blueprint of life. Already, human insulin is being produced commercially, made by genetically engineered bacteria; experiments in animals suggest that it is possible to reverse some inherited disease states by inserting new genes into the host cells.

The databases which currently hold the information about the molecular sequences of DNA, proteins, and other biologically important molecules are swamped with an ever-increasing torrent of data. GenBank^R is a national database containing DNA sequence information; it is administered by the National Institute of General Medical Sciences, and sponsored collaboratively by a number of Federal agencies, including the Library, among other NIH institutes.

GenBank records contain bibliographic data about the published papers which report a particular DNA sequence, a sites and features table which lists in shorthand important aspects about the sequence, and a representation of the actual DNA base pair sequence itself.³ Each of these computer records is composed by a subject specialist who carefully reads the articles listed, and notes the important aspects. As of mid-1986, GenBank had about 8 million base pairs' worth of DNA information, about one million of which is human DNA. This represents less than 0.1% of the human genome. GenBank has a backlog of data yet to be incorporated into the database, because of the labor-intensive nature of its synthesis; GenBank has been growing at the rate of about 1 million new base pairs a year in the past two years. But within the next five to ten years, the automated technology will be at hand to analyze and sequence nearly one million DNA base pairs each day.⁴ An explosive increase in our understanding of life processes will follow only if that information is made available promptly, accurately, and with the kind of specialized analysis tools that allow researchers to identify special characteristics

and patterns among billions of molecules. The National Library of Medicine is embarking on a program to apply its expertise in the building, maintenance, and retrieval of information from large-scale databases, to this data which encodes the molecular language of life.

In order to succeed we will need more powerful tools, and the research to develop these tools is alluded to in the title of this talk, molecules and megahertz. For in finding the significant parts of biological structures composed of literally millions of atoms, we will not be able to succeed without computerized methods of simplifying and graphically depicting how these millions of subunits are interrelated.

For example, a molecular picture of human rhinovirus-14, one of the viruses that cause the common cold, was assembled from protein sequence and crystallographic data by Dr. Michael Rossman and coworkers at Cornell.⁵ High resolution color displays allow each of the viral proteins to be shown in a different color, composing an aggregated unit called a protomer. The entire virus shell is made up of 60 of such protomers. The computer provides the capability to rotate this structure in any axis, revealing the host receptor site pocket and the sites where antibody may bind to neutralize the virus.

Increasingly, the power of computerized graphics will assist clinical practice as well. The computerized tomogram of today will be supplemented by three dimensional depictions of body parts, suitable for modeling of the effects of therapy. Already, computer modeling of complex craniofacial abnormalities is being used to simulate the effects of reconstructive surgery for planning treatment.⁶

Images have always been an important part of medicine and biology. When such images become part of factual databases, they will present special challenges, for although a single letter of the alphabet normally requires a representation by 7 or 8 binary pulses, a picture such as a macromolecule, a computerized x-ray, or a page image from a publication may require millions of binary pulses. Using the types of phone lines and computer modems commonly available today to dial up MEDLINE, such a picture would require 10 or more hours to transmit. Thus, our future scenarios depend critically on improved ability to move massive amounts of complicated electronic information about on demand. In communications engineering terms, sending more signals "down the wire" at the same time requires an increasingly broad spectrum of transmission frequencies; the shorthand for this is the term bandwidth, usually measured in millions of cycles per second, or megahertz.

At the Library's Lister Hill National Center for Biomedical Communications, the computer science, information technology, and communications engineering branches are already at work on both the molecules and the megahertz. As an example, the Electronic Document

Storage and Retrieval research program is investigating the acquisition, electronic storage, and high-speed transmission of digitized page images. The page image retrieval system is capable of transmitting a high resolution image, compressed to about two million bits of information, across a local area computer network in less than four seconds.⁷

In the view of the Lister Hill Center researchers and Long Range Panel Three, the Library of the future defines itself more as a set of widely distributed functions for information transfer than it does a physical place. We have far to go, many remarkable things yet to discover and develop, but in the foggy mists of opportunity, parts of the Library of the future are even today coming into view.

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Medical Informatics: The Emergence of a Discipline

Edward H. Shortliffe

Introduction

The growth of research and development activity in medical applications of computer science, information science, and clinical cognition has been remarkable during the last decade. Despite the escalating interest in such work, it may seem presumptuous to talk about the emergence of medical informatics as a scientific discipline when the name itself generally leads to blank stares or confusion. Yet workers in the field are gradually beginning to feel comfortable with the term as its use increases and as its range of investigational topics is clarified. I suspect it will in time seem no more strange or forced than other neologisms (such as "genetics") did after they had been used by scientists for a few years. The recent decisions by such organizations as the National Library of Medicine, the American College of Physicians, and the Association of American Medical Colleges to embrace the term would suggest that it will increasingly be accepted and understood by workers in the health professions.

Let us start then with an operational definition of the field — a brief description that was formulated by the NLM planning panel on medical informatics research:

Medical informatics is the study of biomedical information, data, and knowledge — their storage, retrieval, and optimal use for problem solving and decision making. The emergence of medical informatics as a new discipline is due in large part to advances in computing and communications technology, to an increasing awareness that the knowledge base of medicine is essentially unmanageable by traditional paper-based methods, and to a growing conviction that the *process* of expert decision making is as important to modern biomedicine as is the fact base on which clinical decisions or research plans are made.

While most of biomedical science is directed at the study of life processes, medical informatics is concerned with the invention and dissemination of powerful information management tools. These include (but are not limited to):

- frameworks for organizing and encoding medical data and knowledge;

- methods for acquiring and representing judgmental knowledge that is acquired through medical experience rather than formal studies;
- computer programs to permit efficient communication among health personnel; and
- systems to provide customized advice so that practitioners may have access to expertise that otherwise might not be efficiently available when and where it is needed.

To clarify these notions and to assist in the planning process, the Long Range Planning Panel on Medical Informatics Research found it useful to formulate scenarios of what *could* and *should* be possible if the nation's technological and research resources are appropriately guided over the next few decades. The recommendations that resulted, and which are briefly summarized later, are best understood in light of such scenarios. Let us consider two brief ones here.

An Introductory Scenario

Picture first Dr. Allen, an internist on a medical school faculty. As is true for his faculty colleagues, he is an attending physician in an outpatient clinic a day or so per week and also attends on the inpatient service for one month per year. He mostly teaches medical students and house staff in such clinical settings, although he has a small private practice as well. He is unusual on the faculty, however, in that his research time is devoted entirely to medical computing applications. Although these scholarly interests motivated his decision to join a faculty, they also affect the way in which he teaches clinical medicine. He shows his students how established computer-based information resources, as well as prototype decision support tools, can facilitate their patient care activities, and he teaches decision science principles in the setting of specific clinical management problems that arise on the ward or in the clinic.

On the day in question, Dr. Allen is attending on the wards and the house staff present him with the case of a lung cancer patient who was admitted the night before with fever, low white count, and mental confusion. A lumbar puncture had been consistent with a bacterial meningitis, and the patient was started on broad spectrum antibiotics. Several questions have arisen, however. Could the CSF abnormalities and confusion be due to metastatic tumor? What has been the recent experience using third generation cephalosporins for bacterial meningitis in patients who are immunocompromised due to neutropenia from oncologic therapy? How well do the agents administered to the patient function in the absence of normal white cells? What cancer chemotherapy has the patient been receiving, when is the next dose due, and how should the

team balance the risks of delaying treatment for tumor control against the patient's evident marrow toxicity?

After examining the patient and noting that he has not improved significantly since therapy was instituted, Dr. Allen begins by emphasizing the importance of obtaining current literature information when handling complex critically ill patients such as this. Using the personal computer and modem in the ward conference room, he calls a commercial information service that will provide online access to the last several years of articles from major medical journals. Searching for information about the use of newer cephalosporins in immunocompromised patients with meningitis, he finds that three pertinent articles have appeared in the last half year. Because the full text of the articles is available electronically, key segments can be perused on the screen and selected for listing on the printer beside the computer. Two of the studies suggest that an alternative agent could be tried in the current patient because of the need to use bactericidal drugs that enter the CSF in adequate concentration.

Rather than leaping to propose a change in therapy, however, Dr. Allen turns to a discussion of the diagnosis itself. How certain is the notion of an infectious etiology in this case? Would additional data help sort out the possibilities? Turning again to the computer, he calls up a diagnostic advice program that assists in the assessment of patients with complex problems in internal medicine. The system is still in experimental form, and its interface makes it difficult to use by anyone except those like Dr. Allen who are familiar with computers and trained in the program's data entry conventions. The program points out that the patient's symptoms and lab results are also potentially compatible with CNS metastases or with a chronic fungal meningitis. It suggests additional tests that would help with the discriminating among these possibilities.

Dr. Allen then points out that the patient has been treated for his lung cancer in the oncology clinic in which a computer system has been used for managing data and generating therapeutic advice in accordance with experimental protocols. He shows the team members how to use the clinic computer to review the patient's past therapy for evidence of nonresponse to the drugs he has received, for early clinical evidence of mental status changes, and to request advice on the advisability of delaying the next course of chemotherapy (now due) while awaiting resolution of the patient's acute problem.

Based on an open discussion of the alternatives, considerations of benefits to the patient, and the new information made available by the various computational resources, the team agrees on a revised plan. Additional diagnostic studies are ordered, but the antimicrobial regimen needs alteration in the meantime pending more definitive data. In addi-

tion, the next cycle of chemotherapy can be safely delayed for at least a few days.

After rounds are completed, the faculty member returns to his office to finish working on a paper and to check his electronic mail. His computer system at the university is tied into a national network that permits him to communicate easily with professional colleagues round the country. He finds that a message is waiting that contains the revised manuscript of a paper he is coauthoring with an individual at another institution. The paper is being written using word processing software on two different types of computer in the homes of the two faculty members. After each makes revisions, he transfers the file to a larger computer, sends it across the country electronically, and his colleague then transfers it to his own small machine for further revisions. Copies of the paper are also shared electronically with students who have asked to see an early version to assist in preparing for their medical computing oral examination. Senior students who have passed such hurdles and are preparing dissertations in the field have also been sent the manuscript and several have returned comments electronically to assist with the next round of revisions. Dr. Allen spends at least two to three hours per day at his computer terminal, sending and receiving messages with colleagues, revising manuscripts, creating examinations and homework assignments for the computing courses he teaches, and running his research laboratory. He can't imagine functioning without such electronic communication facilities and is frustrated when he has to reach by telephone someone who has not yet developed the electronic mail habit.

As some will have guessed, the scenario just described is *not* futuristic, although it could take place today at only a small number of institutions. It is, in fact, a capsule summary of how I and a small number of other academic physicians around the country tend to spend our professional time. Programs such as those mentioned do exist in prototype form, and they can be usefully and safely applied by an individual who knows their limitations and is sufficiently familiar with computers to be able to deal with the interactive requirements. Communication networks for use by scientists are already widespread, although they are used largely in the computer science and aerospace communities and have had only a minor impact on biomedical researchers.* Computers are of

*It is perhaps worth noting, however, that our NLM planning panel coauthored our final report from institutions all around the United States through the use of just this kind of communications network. Text was electronically shared, revised, redistributed, coalesced, and finally sent to the NLM where it was downloaded to personal computers and then directly formatted for printing as a final document.

course widely used in other aspects of health care. The ones mentioned in this brief scenario were selected because they help highlight the current state-of-the-art relative to our planning panel's view of where things could be in another two decades. Let us turn, then, to a view of where we might hope to be by 2006.

Scenario for 2006*

At a remote industrial plant in rural Virginia, where rocket fuel research had been performed in the 1950s and 60s, workers are detoxifying old cylinders containing unknown gases. Some gas is accidentally released, engulfing three men. The rescue squad and the company Environmental Protection Officer (EPO) are immediately summoned. By the time the air ambulances arrive, the men are gasping for breath and beginning to seize. One man experiences a violent opisthotonic convulsion followed by the absence of spontaneous neurologic function. As the Emergency Medical Technicians (EMT) rush the men to the helicopters, the EPO takes samples of the gases in the cylinders for assay in a gas chromatograph/mass-spectrograph. Within twenty minutes, twelve rescue workers, two bystanders and the EPO are exhibiting similar but milder symptoms. What is the gas and how toxic is it? What is the immediate treatment? Will there be long-term effects?

The air ambulance medical station-data analysis unit is fully equipped for video/voice/digital data communications and analysis. While the EMTs connect the men to monitoring systems and take blood samples, the data analysis technician establishes communications links to the EPO performing the gas assay, the Toxicology Information Bank, and the receiving hospital. She verbally reports signs and symptoms and location of the accident. As she speaks, the computer simultaneously processes her words and the patients' physiologic data. The auto-analyzer shows all three patients to be acidotic. The computer in the helicopter, which has received patient data automatically from the auto-analyzer, assesses the bicarbonate requirements and makes recommendations regarding the emergency treatment to be provided by the EMTs. The gas chromatograph-mass spectrograph assay is completed and reported to the EMTs and the receiving hospital: probable B5H9 (pentaborane). All these data become available while the air ambulance is en route.

The EMTs find the men's personal ID wallet cards, magnetically-coded bank cards, that carry critical personal data including health infor-

*The following scenario is condensed from the medical informatics planning panel report. Although it was the product of a joint writing effort, special credit for its preparation goes to Nina Matheson and Steven Pauker. It is loosely based on two recent articles from the medical literature, *JAMA* 254:2603-8 (1985) and *Am J Ind Med* 6:37-44 (1984).

mation such as their medical history and baseline laboratory data. They insert the cards into a special emergency reader, which unscrambles the privacy-protection code and displays the information, including a photograph and dental x-rays for positive identification. At the same time an admission record is automatically created at the hospital.

The hospital's medical information-decision support system recognizes pentaborane toxicity as the likely cause of the syndrome and automatically searches its files for similar cases. There have been none, but the Toxicology Information Bank identifies three cases reported in the literature ten to fifteen years earlier. One patient died en route to the hospital. The autopsy report documented widespread central nervous system degeneration. The other two recovered within the first week with few residual effects. Several animal studies report selective reaction of pentaborane with nervous tissue.

In the Emergency Room (ER), the physician in charge and two residents have been observing the EMT crew at work via the ER video monitor and their personal workstations, which are the size and shape of the clipboards that they once would have used for note taking and analysis. Two of the patients have required blood pressure and ventilatory support. Because there is no information available on long-term effects of pentaborane exposure, the hospital medical information system establishes an individualized follow-up protocol for everyone involved.

Earlier in the day, the personal physician of one of the victims is in his office reviewing tissue specimens with a colleague from the department of pathology. They are organizing material for an article that they will coauthor. On his personal workstation, the internist examines three-dimensional electron micrographs from the digitized versions stored in the hospital's medical information system. The computer circles an area it determines is worthy of comment and awaits a dictated analysis from one of the two physicians, recognizing which one is speaking and subsequently automatically recording and indexing the dictation for the files.

The screen beeps and delivers an electronic voice message from one of their clinical colleagues — a surgeon. "I'm in the OR and would like an opinion on a suspected metastatic lesion. We think the patient is unusually young to have a primary lung cancer. I'm putting the pictures through to your screen." The pathologist, who had notified the hospital system that she would be working in another office, had been easily located by the surgeon. She is an expert on lung tumors and scrolls through the frozen section slide images and chest radiographs. Before committing herself she touches a key at the workstation; both her screen and the one in the operating suite are filled with a window summarizing diagnostic data on all women under the age of 45 who had lung lesions in the last two years.

Data are displayed from her hospital data bank, from the state tumor registry, and from the national end-results registry, segregated by age groups. "It looks like an 85% probability of primary pulmonary adenocarcinoma. Let's look at outcome data." Another keystroke and the under-45 group is displayed by treatment and two year survival, disease-free survival and a stochastic projection of quality-adjusted life expectancy. The most successful protocol is highlighted on the screen. "Thanks," says the surgeon. "I think we'll go ahead."

The pathologist leaves for an appointment elsewhere and the internist turns to a book chapter on which he is working. He is behind, but so are a couple of authors of the other twenty chapters who collaboratively maintain this online textbook. It doesn't matter as much now as in 1986 when all twenty authors had to get their manuscripts together for several editing iterations before going to press. Now, as he revises his chapter it automatically goes through peer review, an editorial process, back to him, and then to online publication. Although physicians can order paper copies, computer tapes, or compact disk versions (depending on their preferences and resources), by far the easiest way is to scan the latest online versions for new information. Of course the new data are also included automatically in specialized databanks and knowledge bases for decision-support. His colleague from pathology couldn't have been so sure of the lung lesion otherwise. Chapters like his are useful for continuing education and refresher reading.

The physician is interrupted by a sudden beep on his monitor. It is an urgent message from the hospital. When he answers, he sees on the screen that one of his patients has just been admitted to General Memorial in deep coma, following an accident at the plant exposing him to pentaborane. The cumulated data and the emergency room physician's report cascade across his screen. Two of the other twelve who have been exposed are also his patients. He leaves for the emergency room immediately.

The Future: How Do We Get There?

It is natural to ask whether the futuristic scenario outlined here is feasible, how much of it is simply wishful thinking, and in what time frame we can expect the innovations to occur. Some aspects of the scenario described are no doubt more than 20 years away, whereas some can probably be achieved sooner.

A key question for those in the medical informatics field, and for those who allocate the personnel, technical, and financial resources that will allow the field to advance, is how to move the limited 1986 scenario along a trajectory to the vision of the future suggested for the year 2006.

Part of the challenge is to identify realistic matches between what *ought* to be undertaken (because of obvious societal good or response to a clear need) and what is appropriate given current scientific knowledge, opportunities for progress, impediments to achieving the goals, and the value of the idea relative to the costs incurred for its development or maintenance. Opportunities for action generally fall into two categories: (1) the enabling activities that will provide the scientific environment needed for both scholarly and practical achievement, and (2) the areas of research that require attention. In the sections that follow, panel assessments of both these issues will be summarized.

Enabling Activities Central to Advancing the Field

The current opportunities for progress in medical informatics derive from several sources, including the rapid growth of awareness and interest in computers and information management systems by health professionals, the growing usefulness of medical information systems for helping with biomedical research and health care problems, and the continuing rapid development of the technological base of these systems so that they can be made increasingly useful. Only a decade ago, computer and software tools were largely unused by health personnel and were viewed with some skepticism. The change in attitudes has been due in large part to three influences:

- the emergence of microcomputers and easy-to-use software, with the concomitant demystification of computers and a general sense in society that such machines are somehow manageable and useful;
- the growing distress among health professionals regarding the amount of information they need in order to practice good medicine; and
- increasing fiscal pressure that encourages the practice of cost-effective medicine, thereby forcing practitioners to consider carefully the clinical utility and reliability of tests, procedures, and therapies — especially when they are expensive or risky.

Gradual changes in attitudes, and increasing acceptance of the *notion* of computer-based tools for health care professionals, are of course not in themselves adequate to assure progress and the adoption of new information management facilities. Early enthusiasm can rapidly sour if the products of research are not responsive to real world needs and sensitive to the logistical requirements of the practice settings in which practitioners work. The achievement of medical informatics research goals over the next two decades is accordingly dependent on practical issues such as the following enabling activities:

- **National Leadership:** Medical computing research has suffered in the past due to diffuse sources of federal support, confusion about the field's relevance to the programmatic needs of established agencies, and a body of peer review scientists that has been small in size and yet still generally underutilized. The field needs an identified national locus for research and related matters that concern the organization and accessibility of biomedical information. With a larger funding base and an acknowledged central role in the medical informatics community, the National Library of Medicine will be in an ideal position to assume this leadership position. Its identification as *the* national center for intramural and extramural research in medical informatics is highly recommended.
- **Institutional Acceptance and Support of Academic Function:** Perhaps the greatest impediment to progress in medical informatics has been its inherent newness and its failure to be recognized as a powerful base on which medicine can and should draw. Many observers view the field as an engineering discipline and fail to recognize that many of the research issues to be addressed are fundamental. This misconception tends to lead to inappropriate expectations about the pace at which progress in the field can occur, and about the levels of support needed for progress. Because the inherent difficulty in the research is often misunderstood, it has been difficult for the field to compete effectively for the limited resources available to support medical investigation.

Similarly, until the field ceases to be viewed in health science schools as a "fringe" activity, the clinical relevance of which is not appreciated, it is unlikely that adequate numbers of high quality investigators (particularly physician-researchers) will be drawn to the field. Recent strong recommendations for academic units in medical informatics, arising from professional organizations such as the American College of Physicians and the Association of American Medical Colleges, are likely to play a significant role in increasing the acceptance of the field and generating resource allocation by schools in the health profession. We are already beginning to see an increasing interest in formal programs in the area arising at several US medical schools.

- **Research Training in Medical Informatics:** The establishment of strong academic programs, and high quality research activities, are of course totally dependent on the availability of individuals trained to assume leadership positions in medical informatics. Training programs have been a priority for the National Library of Medicine, but resources for such students have unfortunately

contracted over the last decade. Expansion of training opportunities, with specific allocation of some support for joint MD, RN, or other health professional degrees, would accordingly be highly desirable. As more academic units are established, the number of institutions offering training opportunities in the field will of course increase as well.

- **Education of Health Professionals:** As the scenario for 2006 suggests, it will not be long before *all* health professionals are necessarily drawn to the use of technological information management aids. The academic units in professional schools will accordingly need to play active roles in training students about computers and their use in medicine (as well as in training future medical informatics researchers). Continuing education programs in medical computing have already begun to show a high level of interest in the field among practitioners. It will accordingly be important for health science schools to develop CME programs for practitioners in their community, to provide training facilities in the field, to encourage student participation in such training activities, and to consider novel approaches to medical education that use computers as adjuncts (ideally simultaneously removing some of the pressure on the overcrowded curriculum of today).
- **Biomedical Communications Network:** The technology for electronic communications already exists, despite the remaining problems related to linking heterogeneous pieces of equipment so that they can effectively communicate with one another. Over the last two decades, the computer science and engineering research communities have gradually become highly dependent on such a network — the ARPANET (developed with funding from the Department of Defense) and CSNET (created with NSF support). As a medium for communication, sharing data and ideas, coauthoring scientific papers, and collaborating at a distance, such computing networks have clearly eclipsed in effectiveness and efficiency the more traditional paper-based or telephonic methods. Government support for a similar communication mechanism for the biomedical research community would have a major “enabling” effect not only on medical informatics but on all areas of biomedical research.
- **Integrated Hardware Environments:** Part of the appeal of networking, whether it be a local network or a national resource like ARPANET or CSNET, is the ability to have a “window on the world” from a single terminal or personal computer. Yet medical informatics research has necessarily used a variety of different computing systems, often with significant incompatibilities that

make it impossible to run two desired programs on the same machine. This phenomenon has resulted at times in a proliferation of computer terminals side by side in medical settings — one for lab results, another for x-rays, a third for doing MEDLINE searches, etc. Integrated hospital information systems attempt to overcome this problem, but the technology is still limited and not generally applicable to private office or clinic settings. As the computer industry develops new technologies for allowing all functionalities desired to be accessed from single cost-effective workstations, many of the barriers to effective implementation of medical information management aids will be overcome.

- **Mechanisms for Setting Standards:** One of the more challenging issues for this developing field is how best to determine when an informatics program is useful, competent, or accurate — especially when the gold standard for what is “right” in medicine is often subject to considerable debate. Evaluation methodologies are accordingly ongoing areas of research in medical informatics (see below), but there is an organizational aspect to this issue as well. National leadership by the scientific community in the field is needed to help establish standards for knowledge verification and system validation — standards that are constructive, and protective of patients and practitioners without being overly restrictive or unrealistic in a new and evolving discipline such as this. As a medical informatics industry develops, such issues will become particularly pertinent.
- **Technology Transfer Mechanisms:** Finally, the proper methods for transferring medical informatics technology from research environments to clinical settings are currently poorly developed. Except for the emergence of database purveyors, vendors of hospital information systems, and office management companies, the medical informatics industry is essentially non-existent. The lack of well defined technology transfer methods, and the tendency for research prototypes to transfer poorly to new clinical environments, have resulted in serious impediments to the dissemination of systems and techniques. Uncertainties regarding legal liability, and the possibility of restrictive federal regulation, have also discouraged companies from developing or distributing clinical decision support tools.

As progress is made in the categories outlined above, the climate will be greatly improved for medical informatics research in the key areas affecting the field and its evolution over the next two decades. These research areas are briefly summarized in the next section.

Research Areas for the Next Two Decades

Although others might structure their list of key research areas differently, it is reasonably comprehensive to claim that central research themes for moving from the current state of the art to the capabilities described in our futuristic scenarios are encompassed in the following seven categories:

- **Knowledge Representation:** The representation of medical knowledge — its expression in mathematical and symbolic form — is critical to the processes of learning, knowing, practicing, and teaching in the health professions. Its representation in permanent form is necessary for its storage, for convenience in transmitting it to others, and for its *use* by automated processing mechanisms. It is this latter point that distinguishes the notion of “information” from “knowledge” in computer systems; a *knowledge-based system* is one that not only stores information in the computer but also uses encoding schemes that capture the semantics of that knowledge so that it can be appropriately *applied* by problem-solving mechanisms in the machine. Despite noteworthy progress in knowledge representation research during the last decade, the problem remains of paramount importance in the development of high performance information management and decision support aids for medicine.
- **Knowledge and Data Acquisition:** Any health professional who attempts to maintain currency in the knowledge of his or her discipline can sympathize with the impossible task of reading and digesting all the new information that is produced. Although computers may have appeal as sources of assistance in the search for pertinent information, there need to be effective mechanisms for acquiring pertinent data and information for machine storage. Even more problematic is the issue of *understanding* information so that it can be applied appropriately when needed. This latter notion is tied to the problem of machine learning, an area of active research. When computer systems can be fed text versions of articles, critique the studies described, and automatically encode the pertinent knowledge for future use in problem solving, a major new kind of decision support function will be possible. Current work to allow experts to “teach” computer systems is one step towards this kind of functionality.
- **Medical Decision Making:** Although the formal sciences of probability and decision theory are well-developed, their effective application in medical settings has been largely elusive to date. Ongoing research is needed to develop decision support mechanisms

that are well integrated into clinical practice, sensitive to clinical needs, and avoid oversimplification or dogma in settings where reasoned assessment by a trained clinician will always be crucial to appropriate decisions. Syntheses of formal decision science notions with the more descriptive decision making ideas drawn from artificial intelligence research may provide important avenues for progress in this field over the next two decades. Recent successes with expert systems in commercial areas are not likely to be reproduced in clinical settings until there has been more research on fundamental problems such as the management of inexact reasoning and the representation and assessment of temporal trends in the course of disease.

- **Cognitive Science:** Closely related to the topic of medical decision making is the need to understand better how experienced clinicians and other decision makers use knowledge, judgment, and intuition to arrive at correct decisions. Equally as important is an understanding of how flawed heuristics and biases can lead to problems in effective medical management. Studies of clinical cognition have already had an impact on research in medical artificial intelligence as well as on clinical teaching. We are likely to see more benefits from this kind of research in the years ahead.
- **Human-Machine Interface:** There is no area of informatics research more important to the field's impact than the development of effective and accepted mechanisms for permitting health personnel to interact with information management tools. Another way in which cognitive science is likely to have an ongoing effect on medical informatics research is in this area: e.g., topics such as the nature of convincing and informative explanations, user modeling, and psychological aspects of communication with machines. Research in this area also involves studies of the use of graphics; ergonomic considerations; alternative interactive devices such as touch screens, light pens, and mouse pointing devices; natural language understanding; text generation; and speech understanding. Medical informatics has much to gain from effective studies and the development of new methodologies in all these areas.
- **Information Storage and Retrieval:** Among the newer technologies that will have a profound effect on the scope and impact of medical information systems is the development of mass storage techniques, accompanied by methods for distributed data processing. For example, such capabilities could make feasible the notion of large nationwide health databases. Related research in data privacy and data integrity are also pertinent to this topic. As data base management techniques continue to mature and evolve,

and the medical appetite for rapid computer-based access to current data and information grows, we will see the development of a natural synergism that results in clinical information resources not currently possible or even contemplated.

- **Evaluation Methodologies:** At present informatics research is both helped and hampered by problems of evaluation design. The design of formal evaluation has its own disciplinary apparatus and methodology, but incorporating these techniques for the validation of informatics technologies has often been difficult, both conceptually and in practice. Particularly difficult has been the determination of acceptable levels of performance in areas where there is often disagreement among professionals, even among experts with similar training and experience. We need to see a more adequate theory and technique, accepted by the medical informatics community and health science professionals. It is especially important that appropriate evaluation guidelines and methods be developed for the validation of medical knowledge bases and decision support systems.

Summary

Our planning panel on medical informatics research was guided by an effort to anticipate future health care and research needs and the role that information and communication technologies could play in responding to them. We developed a scenario for the future (excerpted above), elements of which may be achieved in 20 years or so if research and logistical resources are properly applied. The goal was to identify the opportunities for the medical informatics field, the barriers that are hindering progress, and to suggest research and logistical activities that would heighten the chances of reaching the 20 year goal on schedule.

Medical informatics research has already made enormous strides, but the problems of transferring research products to clinical environments continue to hinder its full impact in the health care setting. Several recurring points were made by panel members as they considered the logistical needs of the field:

- National leadership is needed to develop the infrastructure for more effective sharing of research results, their improved evaluation, and their facilitated dissemination. Particularly appropriate would be identification of the National Library of Medicine as the central government organization for the medical informatics field, one that works closely with the rest of NIH and complements the information dissemination and knowledge management activities of the other institutes.

- There is a major need for the establishment of a national communications network, perhaps initially for medical informatics researchers, then for biomedical researchers, and ultimately for the entire biomedical community.
- We eagerly await the formal establishment of centers of excellence in medical informatics research. Related issues are the need for training programs in medical informatics and strong funding programs for Research Career Development and New Investigator Awards.

Efforts to coordinate resources and provide leadership are of course only pertinent if they are designed to support a strong investigative program in medical informatics. Research priorities during the next two decades will be guided by our need to acquire, structure, provide access to, and teach the knowledge of medicine and health:

- We must *accumulate* and *synthesize* medical expertise so that it is easily accessible to the next generation as well as to individuals in the present generation. This requires an understanding of the semantic structure in data and knowledge and the development of effective methods for encoding medical information.
- We must *deliver* knowledge and relevant data, providing it more reliably, more cheaply, and with greater selectivity than is possible with present methods (books, journals, consultants, and today's computer-based resources).
- We must *teach* the knowledge of medicine and health in new ways that are both sensitive to the limitations of human memory and of traditional classroom approaches and guided by emerging technologies for instruction and self-study.

These goals require focused research in several key areas of medical informatics. High priority is placed on research in cognition and decision support, on the development and use of knowledge and databases and on the development of new methodologies for evaluating the results of medical informatics research.

It is a humbling experience to try to anticipate the future as our panel was asked to do. The world is radically different from what any of us would have predicted two decades ago, and there is little reason to believe we will be any more correct in trying to anticipate what lies twenty years in the future. Yet it is in the attempt to do so that progress is made, for views of what *ought* to be or what *might* be are the source of inspiration and can subsequently affect decisions regarding resource commitment. The panel strongly encourages the commitment of resources that will allow progress in medical informatics to take its course. The health care of the nation has much to benefit when the stated goals are achieved.

Assisting Health Professions Education Through Information Technology

Octo Barnett

Introduction

American health care and the American system of medical education are considered to be among the best in the world. By and large, our professional schools produce knowledgeable, compassionate, responsible, and technically competent health professionals. Why then should there be any concern with the content and methods of education of health professionals?

The Present Situation

Within the last few decades, powerful forces have radically changed the scope and complexity of the health sciences and the delivery of health care. These forces are continuing to influence the shape of health care, altering the body of medical knowledge, changing the way health professionals practice their craft, and modifying the system of health care delivery.

It can be argued that we are in the beginning stages of a new age of medicine. Recent advances in medicine, particularly in molecular and cell biology, immunology and neurobiology, have opened new paths to preventive, diagnostic and curative strategies of astonishing power and subtlety. Progress in the fields of dentistry, nursing, pharmacy and other health professions has yielded new strategies for maintaining health and dealing with illness.

This explosion of knowledge, combined with the aging of the population, the shift from acute illness toward chronic disease, the emphasis on cost containment, the increasingly corporate nature of health care delivery, and the availability of information processing technology is radically changing the way that health professionals function today. These factors will surely alter even more radically the way that health professionals of the twenty-first century practice.

One obvious effect of the expanded knowledge base is that any single individual can master only a decreasing fraction of the total spectrum of the available information. As a result there has been a rapid

growth in the number of health disciplines, and of specialties within disciplines, yielding an increasingly fragmented clinical practice.

Despite these major advances in the science and technology of health care, and despite the new challenges to health care, the training of physicians is little different today from what it was a half-century ago. For all of the health disciplines, the structure of education still primarily consists of lectures in which a procession of teachers relate large quantities of scientific material to a passive student audience. Current methods of instruction in the health sciences cannot meet the challenge of the exponentially increasing flow of new discoveries. The explosion in medical knowledge has placed impossible time demands on the curriculum, and has far outstripped the ability of our students to memorize the quantity and complexity of scientific knowledge. We cannot increase the duration of professional education; we cannot continue with the increasing trend toward the fragmentation of narrow specialization; and we cannot depend on continuing education to fill the gap.

One valid response to the problem of information overload is to take advantage of information technology to facilitate learning and to provide easy access to appropriate information sources for the practicing health care professional. Computer-based educational applications can facilitate acquisition of essential knowledge and mastery of problem-solving skills. Comprehensive training and experience with modern methods of information management during the students' formative years will greatly enhance their effective functioning as health care practitioners and as professionals committed to life-long learning.

In emphasizing the importance of information technology in the education of the health professional, we recognize the inherent tension between the changing and unchangeable aspects of health care. Information technology has the potential to address the everchanging and everbroadening mass of knowledge concerning the etiology, prevention, and treatment of disease as well as the maintenance of health. This use of technology, however important, must not distract from the fundamental human aspect of care: the relationship of an individual health professional to an individual patient.

The role for information technology concerns content, but even more importantly, concerns the method of education. Students should be given fewer 'answers' and more 'tools' — tools for self teaching and for synthesizing, framing, and revising knowledge. They should have the opportunity to practice, from the earliest days of professional education, skills of seeking out information, of testing hypotheses, and of solving problems. The underlying objective in the use of information technology in health sciences education is not so much the transfer of current infor-

mation, but providing an environment which encourages the student to take increasing responsibility to become an independent learner.

The increasing interest in the development of clinical decision-assistance programs offers a major opportunity for the application of information technology in medical education. These programs range in complexity from simple "if-then" rules which provide reminders to clinicians in cases where pre-specified protocols are violated, to programs which are at the forefront of artificial intelligence research and whose performance can rival expert clinicians in well-specified, limited challenges. One of the more exciting aspects of this research is the range of new insights being provided into the nature and process of clinical reasoning.

Another promising application of computer technology in medical education is in the simulation of complex biological systems. Prototype computer-based simulations include the simultaneous interaction of a number of variables and closed-loop feedback control.

These programs use methods that range from simple random assignment of patient "states" (such as the value of the blood sugar in a simulation of diabetic ketoacidosis) to complex modeling of physiological systems such as cardiovascular regulation. Coupling these models with high-resolution graphic displays and computer-controlled video disk presentations greatly enhances the teaching potential.

Role of the National Library of Medicine

The NLM has been a pioneer in promoting easy and inexpensive access to the published literature. The advances made possible in bibliographic retrieval by NLM have impacted more members of the health care community than any other single application of information technology. The development of the MeSH (Medical Subject Headings) indexing system and the MEDLARS accessing system have contributed enormously to education at the undergraduate and graduate levels. Decreasing cost and increasing availability of personal computers, together with the advent of reasonably priced MEDLARS accessing services, have placed bibliographic access within the reach of the average practitioner and brought closer the goal of each professional having ready access to any desired medical knowledge independent of the time and place of need.

The NLM has been one of the most important institutions in making information readily available to the health science professional. Although this role has been considered in the past to be primarily one of storage, indexing, and retrieval of paper documents, a more relevant and timely

definition of NLM's role would frame the mission in terms of knowledge management.

Knowledge management may be defined as a set of methodologies for the acquisition, organization, and maintenance of a knowledge base to facilitate retrieval of specific information. The user of the knowledge may be a clinician, a student, a researcher, an educator, or an administrator. The knowledge maintained by a knowledge management system may be of two general types. The first is a conceptual framework or schema which defines organization and relationships within domains of knowledge. The NLM's MeSH vocabulary is one example of a conceptual framework: the hierarchical organization of the MeSH terms defines an explicit relation among the different terms in the nomenclature.

The second type of knowledge management system provides access to content knowledge in either structured or unstructured form. Structured knowledge is information stored in a form that can be easily accessed by key ideas or concepts. In a book the chapter headings and index represent a primitive form of structured knowledge. Much more sophisticated examples of structured content are electronic textbooks such as the Hepatitis Knowledge Base which was the subject of active experimentation by NLM. Structured knowledge can also exist in the form of procedures or methods for accomplishing specific tasks. Unstructured content, on the other hand, includes narrative text found in traditional textbooks and in the archival journal literature, as well as pictures, graphs, etc.

Developments in computer and communication technology have proceeded at an astounding pace in recent years and show no sign of slowing down. There is general optimism that even the most ambitious potential applications of information technology to education in the health professions will soon become both technically feasible and economically possible.

At the present time, available technology enables routine data collection, information storage, manipulation and display, and a variety of forms of automated record keeping. In many settings, students, faculty, and practicing physicians have access to convenient, compact and powerful personal computers. Network communication between individual workstations and institutional computer resources is becoming less expensive and more versatile. Powerful, easy-to-use authoring languages facilitate creation of exciting educational programs for the health professional. The display of information is becoming increasingly effective with higher resolution graphics and the use of color. Radically new forms of user interaction are made possible by innovations such as "pull-down windows" and various types of pointer devices (the "mouse" being one popular example.) Computer controlled video disks allow easy

manipulation and display of either still images or scenes with coordinated sound.

These developments represent the technology of the present; to try to predict the possible technologies of the future is most difficult. It is safe to predict, however, that there will be much more powerful, smaller, and less expensive computers, with much higher-resolution graphic displays, and much better communication capabilities. The limiting factor of educational applications for the health professional will not be primarily hardware, but more a paucity of easily available and appropriate applications.

There are real and exciting potential applications of information technology which can revolutionize the education of health professionals. Indeed, some of the most critical weaknesses of present health care education, and more importantly, some of the most important opportunities for the future, can only be met through the imaginative and comprehensive use of information technology. The NLM has had an admirable role in the past in facilitating the storage and dissemination of medical knowledge. In the future, the role of NLM can be even more important in supporting the application of the full range of information technology to the education of the student in health sciences and to the support of the practicing health professional.

It is obvious that the subject of information technology in the education of health professionals is both broad and complex. For many years, the limitations of the technology, (e.g., expense, unreliability, difficulty of use), prevented both clinicians and educators from transferring even routine tasks to the computer. The technology has developed dramatically in recent years, and we now find that there the major problem is the lack of applications and methods of dissemination to take full advantage of current capabilities.

It also is obvious that certain aspects of the application of the technology will need to be expanded even further to meet tomorrow's needs. Without proper expertise and organizational resources, this nation will place in jeopardy the quality of education and practice of its health care providers, and consequently, the quality of its health care.

There are four areas that seem fundamental to assisting future health professional education through information technology. These four areas are: Unified Medical Language System, Centers of Excellence in Health Sciences Informatics, Knowledge Management Systems, and Educational Technology itself. The first two are necessary prerequisites to exploiting today's technological capabilities, and are vital to meeting future needs. The latter two push the boundaries of today's capabilities and pave the way for providing the environment that will be needed for the health care community of the future.

Unified Medical Language System

A major impediment to widespread adoption of computer-based information systems in health care has been the absence of a standard vocabulary for describing health care phenomena including patient care, results of biomedical research, and the managerial and business transactions of ambulatory care and hospital activities. In order to integrate computer-based information systems in the health sciences, there is a need to link the vocabulary used for the recording of patient data in the clinical setting to that used for indexing scientific, clinical and behavioral literature; this vocabulary must also be compatible with the terminology used in health science education, in health-care administration, in medical reimbursement and in health-related social and engineering disciplines.

At the same time, the increasing use of automated information systems increases the need for common terminology in order to minimize the need for manual translation of clinical content. A major resource commitment will be required to develop methods wherein a uniform language can be easily used in a professionally acceptable fashion in all the health disciplines. Leadership will be required to overcome habitual recording practices and automatic responses that do not consider integrated uses of documents.

A major accomplishment in the development of a unified medical language system is the worldwide adoption of NLM MEDLARS (based on the MeSH indexing system) for access to bibliographic citations of scientific literature. NLM and professional librarians in schools and hospitals have had a major leadership role in developing extensions and enhancements to the MeSH vocabulary and in promoting the use of this example of a standardized vocabulary. However, MeSH is insufficiently detailed for clinical care, for specialty areas, and for many of the health professions outside of medicine. A common language can be ultimately derived on a comprehensive basis only within a common conceptual framework. Reconciling existing frameworks will be difficult; accommodating the language from those disciplines that have not yet identified a common framework will make this task even more difficult.

The language developed in specialized areas is resistant to change by outside pressures. The proposed development of a unified language requires a major collaboration among NLM, the different professional societies, academic organizations, professional boards, credentialing and licensing boards, reimbursement agencies, editors of professional journals, and relevant government agencies. Collaboration on this scale will be enormously difficult to orchestrate. Each group and subgroup will have interests to protect, both professional and financial. Those who

have invested the most in prior standardization may have the most to lose. There will be an enormous inertia and resistance on the part of many clinical professionals to change long-standing habits of expression. The need for international interchange of information and efforts in standardization add to the complexity. An enormous dedication, imagination, and continuing leadership effort on the part of NLM will be required.

The planning panel on Health Professions Education made a number of recommendations regarding the desirable role of NLM in promoting the development of a Unified Medical Language System. Some of the more important of these recommendations are:

1. That NLM make use of the extensive experience of MeSH development and usage to begin at once to develop extensions of MeSH to index health system clinical information and to provide a nomenclature for health professions other than medicine. Furthermore, NLM should continue to identify new terms and relations between terms by automatic monitoring of the full text of citations stored in the NLM computer-based data bank.
2. That the NLM develop collaborative efforts with specialty societies and with other health disciplines and professions to extend the MeSH thesaurus into clinical care records, connecting terms used in their fields to broader, narrower and related terms in the existing thesaurus. Professional societies in all areas of health care should be involved, as well as representatives of the insurance industry, relevant government agencies, and editors and publishers of literature and software oriented toward the health care community.
3. That the NLM promote and support extramural projects that focus on the use of a Unified Language in interactive, computer-based clinical information systems. NLM should give a high priority to gaining experience with such standardized vocabularies in operational medical information systems used in a variety of settings and by the full spectrum of health professionals.
4. That the NLM support extramural projects to develop standard vocabularies modeled on MeSH. These vocabularies must take into account the specific concerns of the various health disciplines and the subspecialties of the disciplines. The necessary support utilities must be developed, (e.g., dictionaries of terms, a thesaurus, cross-indices, automatic classification and indexing assistance tools, and computer programs to validate the literature and medical records which use the vocabulary). This should be followed by automated indexing and classification of clinical records and literature by these standard terms.

5. That NLM encourage the development of computer-based instructional programs that utilize the Unified Language. The committee strongly believes that it is essential to inculcate from the beginning of the health science student's education the necessity for and usefulness of a common language.
6. That NLM undertake and sustain long-term initiatives and collaborative efforts to promote the use of the Unified Language by editors and publishers of journals, books, computer programs and other media produced for health professionals.

Centers of Excellence

Informatics in the health sciences is a developing field of applied science which has made admirable progress in the past decade. A major factor in this program is related to the leadership of the NLM and a few individual academic laboratories (often sponsored by NLM research grants). In addition, private industry has become more aggressive in developing and marketing information technology support systems, such as hospital information systems, bibliographic reference systems, and electrocardiographic analysis systems. However, the promise of information technology in medical applications has only begun to be tapped and there is a pressing need to support and promote work in this field.

Many of the significant advances in medical informatics have come about in combined academic/clinical environments where there has been a combination of administrative support, substantial stable funding, and expert human resources. Such environments are unusual, however. Many of these units have evolved more as a matter of the combination of the individual initiative of a few creative individuals and fortuitous circumstances rather than planning. In order to promote more rapid advancement in the field of medical informatics, well-planned Centers of Excellence are needed to provide the combined academic/clinical environments, stable material resources, concentrated expertise, and increased visibility for the field. Such Centers will provide a highly visible critical mass of individuals, capable of exploiting and expanding computer technology for the ultimate goal of high quality, cost-effective health care.

Health Science Informatics is attracting many bright young individuals from the health and engineering professions as well as from medical library science and academic administration who have the potential to advance the field. Without advanced training and opportunities for research, this resource will likely not be tapped to its full potential. Centers of Excellence would enable the nation to develop and expand a highly skilled cadre of researchers in informatics for all the

health specialties; they would provide long term career support and job opportunities in order to keep talented individuals in this highly important field.

A Center of Excellence should have the following characteristics:

1. Each Center of Excellence should have a strong research focus and significant educational and training components. In addition, each Center should provide a leadership role in introducing the use of information technology in professional education and in stimulating the introduction of Health Science Informatics content in the curricula of the different professional schools.
2. Each Center of Excellence should incorporate a true multidisciplinary approach. In particular each Center should develop a substantial relation with the operational health delivery system, the practicing health professional and the health science library community.
3. Each center should provide a "rallying force" for intra-institutional and interinstitutional sharing; the different centers should be encouraged to collaborate in an effective consortium to encourage joint development and in sharing information regionally and nationally.
4. In each Center, NLM should support training of highly skilled career investigators, provide adequate core research funding, and support career development programs for experienced researchers (including individuals visiting from non-Center institutions).
5. In order to apply for a Center of Excellence award there should be a demonstrated commitment at the institutional level by the administration and academic leadership of the institution.
6. Additional criteria for an award should be a willingness of the proposed Center to collaborate with other Center awardees in a consortium arrangement so that each Center can benefit by, and build upon, each other's experience. One of the most important criteria should be the extent of the promise of the proposed Center to facilitate the dissemination of its accomplishments and contributions to other professional schools and to practicing health professionals.
7. In order to assure productive outcomes, a number of preconditions should be met by the applicant institutions/organizations. These should include evidence of administrative support; a minimum required level of salary support commitment by the institution; pre-existing resources such as computer equipment and space; a core staff who have demonstrated previous achievements in medical informatics; evidence of support for the conver-

sion of the institution's library into an information management center able to participate fully in medical informatics programs; and evidence of the willingness of the curriculum committees to integrate training in Medical Informatics with other parts of the professional curriculum.

The panel was strongly united in its belief that the funding of Centers of Excellence should be given the highest priority by the NLM.

An important impediment to establishing a number of Centers of Excellence is the need to provide the funds for long-term stable support. The NLM must have sufficient funds and an appropriate funding mechanism to provide such support.

Funding of a Center would be for a minimum 5-year period (at a level of approximately one million dollars each year for each Center) to fulfill the function of training and dissemination and to provide the necessary commitment required to build and support a Center's research infrastructure and ensure continuity for productive research and development.

Funding would support staff resources and core project activities. Each Center would also compete, as would other investigators not affiliated with a Center, for the available funds NLM has in its budget base to conduct additional investigator-initiated research projects not part of the "core" research. Center-based investigators would of course be encouraged to seek funds from other federal and from private sources as well.

Major reasons to provide a high level of stable support for the proposed Centers of Excellence are to encourage the evolution of institutional role models for the field and to support the development of applications in medical informatics that can be readily disseminated. In addition, a fundamental component of the Center concept is to stimulate a high level of collaboration between different institutions. The NLM will need to develop review and funding mechanisms that foster such an attitude.

Knowledge Management for Practicing Health-Care Providers

There is general acceptance of the claim that practicing health professionals could benefit from greater access to current information about optimal diagnostic and treatment strategies and appropriate use of drug therapy. However, there is a paucity of specific data on the details and frequency of the clinical problems and the decisions that a health care provider is required to make in the course of his/her daily practice. There is even less data as to whether and to what extent improved acces-

sibility of relevant information would improve the quality of health care or increase the cost-effectiveness of health care delivery.

Descriptive research is needed that would delineate the information needs of the practitioner in various settings. Demonstration projects are required to gain experience in utilizing computer technology in "knowledge management systems" that guide and serve the practitioners. Evaluative research is needed to determine the utility and effectiveness of the knowledge management systems in clinical practice.

A knowledge management system should be tightly linked with a computer-based medical record system so that the information activities of clinical practice can be integrated with continuing education. This requires a well-designed interactive computer system that would both support routine information needs and provide ready access to appropriate knowledge bases (e.g., drug information databases, databases on appropriate use of specific tests, and information on effective diagnostic strategies).

A knowledge management system has the potential of providing integration of the recording activities of a clinical practice with quality assessment and assurance activities. There is a pressing need for clinical information systems which allow the systematic analysis and quality assessment of practice patterns. Such a system should have the capability of providing feed-back when deviations from pre-defined quality assurance protocols were detected. Two overriding design considerations are that the knowledge management systems be affordable by both the self-employed health care practitioner or by organizations which employ health care practitioners and that they be relatively simple to access and use.

The increasing complexity of medical care, the continuing knowledge explosion, and the necessity to consider costs in diagnostic and therapeutic decisions make it more necessary than ever for health-care providers to access and utilize the most current reliable information in making decisions about their patients. Health-care practitioners must be trained to rely less on their memories and more on their ability to obtain problem-specific knowledge, to appraise it critically and to utilize it appropriately. In medicine, the need for such orientation is one of the major tenets of the Report of the Panel on the General Professional Education of the Physician and College Preparation for Medicine (the GPEP Report) of the Association of American Medical Colleges.

As an aid to both clinical decision making and education in the health professions, computer technology can play an important role in knowledge management and knowledge retrieval. The traditional role of the NLM has been in the cataloging, storage, and indexing of paper documents. The availability of electronic storage of such information

now offers a radically new opportunity for the NLM to make clinical and scientific information much more available and accessible to the health care professional. The mission of the NLM should evolve from being primarily one of document storage to one of knowledge management.

The design of useful knowledge management systems for health care providers depends in large part on three factors:

1. the size, completeness, and the quality of the knowledge bases available;
2. the availability of effective tools to allow easy and timely access to appropriate portions of the knowledge base; and
3. the implementation of appropriate methods of generating, updating, and controlling the quality of the information.

Creation of such knowledge bases will not proceed actively until there is reasonable expectation on the part of authors and software publishers that health care practitioners will find computer-based knowledge management systems attractive. On the other hand, practitioners will not be tempted to employ such systems until there is a critical mass of content that is easily accessible.

A similar limitation is that administrators of health care organizations and financial reimbursement agencies will not likely provide financial support for access to knowledge bases for health care professionals until their impact on effectiveness of decision-making and utilization of resources has been demonstrated. Prototype, exploratory developments and initial evaluation efforts are essential in order to overcome these barriers.

The panel recommended that NLM develop an extramural research support program for projects aimed at the development, use and evaluation of prototype knowledge systems, with the specific characteristics that this extramural research support should:

1. Stimulate the development of functioning prototype knowledge management systems and make them available to selected users, gain experience with the use of these prototypes, and obtain feedback about problems, limitations, and needed capabilities. These systems should be designed to be used directly by health professionals in daily practice and should integrate routine clinical information processing with knowledge retrieval. They should include user-interface methods and tools to facilitate targeted knowledge retrieval, browsing, and decision support. In addition, NLM should seek to establish collaboration with federal reimbursement agencies and with private health insurance companies to establish mechanisms so that the costs of developing operational prototypes be shared by agencies that would directly or indirectly benefit by their use.

2. Undertake programs that would lead to a critical mass of content for inclusion in a knowledge management system. As part of the effort to evaluate quality of content, NLM should undertake to establish an active collaboration with other organizations, in particular professional societies and credentialing, licensing and reviewing boards, to develop mechanisms to support the acquisition and organization of the expert knowledge base. NLM should also seek active collaboration with such organizations in studies directed at evaluating the dissemination and utilization of specific knowledge-management-system applications.
3. Fund research aimed at resolving potential problems and issues related to the development and maintenance of knowledge management systems, including:
 - Improved understanding of the information-seeking behavior and the access needs of practicing health-care providers;
 - Consideration of the different behavior involved in targeted, problem-solving knowledge retrieval versus browsing versus decision support;
 - Development of specifications for preparation of material for inclusion of medical knowledge in an "electronic textbook" format and consideration of mechanisms for content update and revision as needed;
 - Delineation of software engineering issues involved in computer storage and access of large and complex medical knowledge bases.
4. Support research aimed at determining to what extent a practice-linked, knowledge management system could facilitate cost-effective decisions and more judicious use of available resources.

Educational Technology

Technology exists to provide students with a wide variety of tools and aids to learning, including computer-assisted instruction, computer-based simulations, word processing, bibliographic retrieval, self-testing and appraisal, electronic textbooks, personal file management, and electronic mail. Many professional schools currently make at least some of these tools available to their students, and increasingly students are acquiring personal hardware and software for facilitating schoolwork.

Enlightened educators and students sense the potential of this technology, but are frustrated that the current piecemeal approach prevents the full realization of this potential. They envision a curriculum where technology is fully integrated into all coursework, and where all faculty and students have access to similar (and compatible) resources.

There is increasing recognition among health science educators that it is important to provide the student a greater degree of control over his/her education through the encouragement of personal initiative, self-directed learning, and frequent opportunity for self-assessment. Students

are generally comfortable in making use of the computer and react positively to its use in instruction. Schools in the near future will probably require students to acquire computer equipment, just as microscopes and stethoscopes are now required; in addition, many students will have gained considerable experience via elementary and high school computer courses and are presently using their own personal computers.

Increasingly sophisticated students and instructors will be able to take advantage of expanded technological capabilities such as interactive videodisk, animated graphics, physiological and epidemiological modeling programs, and networked student/faculty workstations. This will provide the impetus for computer-based instruction to shift from drill and practice toward a more responsive tutorial style. Programs will be increasingly interfaced with particular problem areas. They will be able to leave initiative to the student, to recognize common student errors, and to provide advice when requested. The comprehensive use of information technology in the education of health professionals will have far-reaching effects. The student who uses the computer as an indispensable tool during the formative educational years will undoubtedly find it an indispensable partner in future practice.

There are a number of impediments to the widespread use of information technology in medical education. As is true of many developing fields, there is a lack of standardization in educational technology that inhibits the sharing of materials and methods. There is a built-in conflict between the goals of developing exciting and stimulating prototypes and the standardization of methods.

Faculty efforts to develop and use educational technology are fragmented and insufficiently supported either by the local institution or by external funding. This limitation is particularly true with regard to the development of computer-based materials, since such activity is very time consuming and is rarely considered a research contribution. In addition, publications in educational or information technology journals do not provide the same recognition for promotion purposes as do papers in traditional research journals.

A number of health science schools have developed audiovisual departments with varying success. However, it is rare for there to be an institutional organization in place to assist with the development of computer-assisted instructional software. There may be individual faculty members interested in this activity at any given school, but the development is often fragmented with little over-all plan and little integration of either software or hardware, and little sharing of resources or support personnel. Related to the scattered nature of educational technology development, there is no comprehensive cataloging of instructional soft-

ware, and very little interchange of materials from one institution to another or indeed, even among disciplines within a single institution.

The panel made a number of recommendations regarding how the NLM could play a major role in developing educational applications of computer technology. Some of the more important recommendations were:

1. That NLM support development of novel forms of applications of information technology that have the potential for significantly different and more powerful educational impact. Possible examples include the use of computer models that have the ability to interact with the student in a consultative or explanatory fashion, programs that provide realistic simulations of patient cases and simulations of physiological systems.
2. That NLM promote the development of "standardized" authoring languages and programming toolkits to facilitate national dissemination. An analysis of existing tools that have proven useful should be undertaken. These languages and toolkits would enable the production of educational software at a sufficiently high level of abstraction to match different educational philosophies and different specific technologies.
3. That NLM develop mechanisms for specific review and documentation of the available educational software, and that NLM develop a system of cataloging transferable programs. This software should be indexed in the appropriate health science indexes (*Index Medicus*, *Cumulative Index to Nursing and Allied Health Literature*, etc.) so as to be accessible in the same manner as journal articles.
4. That NLM promote the publication of reviews of the available computer-based educational programs by professional journals. NLM should work with appropriate professional societies to develop techniques and standards for review of the computer-based programs.
5. That NLM support the development of Model Curricula where technology is fully integrated into the design, management, and delivery of a particular health science educational area. NLM should provide support for faculty time related to integration of computer technology into coursework, including development of course-related instructional programs where needed. Support should also be provided for acquisition of hardware and software, and for preparation of the academic health sciences library to serve as a participating unit.
6. To promote access to computer-based educational resources, NLM should:

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- Publicize the availability of resources that have been catalogued.
 - Support improvements to its National Learning Demonstration Center as a location where visiting scholars can explore existing materials in a variety of health-related subject areas and use various computer and video educational technologies.
 - Support the development of Demonstration Centers in other locations where faculty can observe and use computer-based educational applications.
 - Promote increased faculty and librarians' knowledge about the use of educational technology through support of training in medical informatics and by sponsoring fellowships that can provide increased knowledge of educational technology. Such training would be an appropriate part of the proposed Centers of Excellence program.
 - Support annual conferences, "trade-shows", seminars, and demonstrations where the new developments in educational applications of information technology can be reviewed and evaluated by invited decision-makers in medical education.

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